The Davis Island Lock and Dam 1870 - 1922

Leland R. Johnson

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THE DAVIS ISLAND LOCK AND DAM

1870-1922

Colonel William E. Merrill
Father of the
Ohio River Improvement

Pittsburgh District

THE DAVIS ISLAND LOCK AND DAM

1870-1922

Leland R. Johnson

U. S. Army Engineer District

Pittsburgh, Pennsylvania

1985

FOREWORD

Though long abandoned and removed from the Ohio River channel, the Davis Island Lock and Dam project continued to interest both engineers and historians at its centennial in 1985. Located about five miles downstream of the Point at Pittsburgh, it created a harbor for Pittsburgh extending up the Ohio and short distances up the Allegheny and Monongahela rivers on both sides of the Point. At its completion in 1885 it provided reliable year-round navigation and water supply along the Pittsburgh waterfront. By improving transportation and water supply in Pittsburgh's harbor, the lock and dam encouraged waterfront industrial development and thereby had incalculable but significant influence on the city's history. Because it was the first lock and movable dam built on the Ohio, it also influenced the regional history of the Ohio River basin; and the experimental engineering used in its design and construction made it significant to the national and even international history of waterway engineering technology.

The planning, design, and construction of the Davis Island project made it an engineering experiment of enduring import, a landmark in the annals of waterway technology. At Davis Island, the U. S. Army Corps of Engineers conducted some of its earliest hydraulic model studies and engaged in one of its first systematic studies of international waterways technology. Those planning studies resulted in the construction at Davis Island of the largest Chanoine dam built in the 19th century, of one of the earliest concrete structures built by the Corps of Engineers, of the first rolling lock gates, and of the largest navigation lock in the world at the time. Experimentation after completion of the lock and dam resulted in additional project modifications which improved its design and operational capabilities, with major improvements which were adopted at the locks and dams subsequently constructed.

At Davis Island, innovative technological devices and operational procedures were developed that made possible the canalization of the

Ohio River, first to a six-foot and later to a nine-foot depth through the construction of fifty more locks and dams, all modeled upon the structure completed in 1885 at Davis Island. That canalization in turn facilitated waterway transportation and the related riverside industrial development which has altered Ohio River basin and national history. The international planning studies at the Davis Island project during the 1870s have also, to various degrees, influenced waterway project design throughout the United States, contributing immeasurably to the development of the modern waterway transport network serving all Americans.

This centennial history of the Davis Island project outlines the challenging planning, design, construction, and operational difficulties met and solved by the Army Engineers on the Ohio River during the waning years of the 19th century. It also provides some initial analyses of the project's effects upon the history of Pittsburgh, of the Ohio River basin, and of the nation, along with a discussion of the project's significance to waterway engineering technology. The construction and operation of the Davis Island Lock and Dam placed the Pittsburgh District of the U. S. Army Corps of Engineers in the vanguard of experimental waterway engineering, a place which it has maintained throughout much of the 20th century, and it therefore takes pardonable pride in the achievements of the Army Engineers at Davis Island.

Richard A. Rothblum

Richard A. Rothblum
Colonel, Corps of Engineers
District Engineer

The Author

Leland R. Johnson, Ph.D., is director of Clio Research Company which prepares historical and technical studies under contract with businesses, trade associations, and governmental agencies. He is the author of many articles and books and has written the histories of the four Engineer Districts within the Ohio River Division.

PREFACE

As the first of fifty-one locks and movable Chanoine dams built by the U. S. Army Corps of Engineers on the Ohio River between 1878 and 1929, the Davis Island Lock and Dam at the head of the river near Pittsburgh established the design, construction, and operation precedents for the remainder of the structures. Because it was the pioneer slackwater project on the Ohio, it has long attracted my attention during a twenty-year study of navigation improvement and water resource development in the Ohio River basin and throughout the nation. Even in 1971, when preparing a history of the locks and dams built on the Ohio near Cairo, it was necessary to study what had happened at the Davis Island project during the 19th century in order to understand developments on the lower river during the 20th century. I had long hoped for an opportunity to review the Davis Island project history in some depth, and I am grateful to the Pittsburgh Engineer District and its personnel for providing that opportunity under contract in 1984.

Lieutenant Colonel John L. Richards initiated this historical study as the 1985 centennial of the Davis Island project's completion approached, and the study was completed under the administration of Colonel Richard A. Rothblum. Without the support of those two Pittsburgh District Engineers the study would neither have been undertaken, nor completed; it was their sensitivity to the historical significance of the Davis Island project which made this study possible.

The District Engineers created an informal committee of experts to administer the contract, guide the contractor, and assist with completion of the historical study. They were: Jacque S. Minnotte, the former chief of the District's Engineering and Construction Divisions and engineer advisor to the District Engineers; George Muschar, the District's executive assistant; John A. Reed, chief of the Public Affairs Office; George Cingle, Jr., chief of the Planning Division; James A. Purdy, chief of the Environmental Studies Branch; Conrad E. Weiser

of the Environmental Studies Branch who collected the illustrations and maps and coordinated the reviews; Don W. Barry who undertook the publication's layout and design; and Dr. Martin K. Gordon who coordinated the review at the Office of the Chief of Engineers' historical division. I appreciate the contributions of each to whatever merits this study may possess.

The contract could not have been completed on schedule without the invaluable assistance provided by Frank Stocker, who guided me on an arduous tour of the Davis Island site, by Charles "Chuck" Parrish who helped scout the historic engineering works of Pittsburgh, by Joseph Sheehan who made available the material at the Philadelphia Federal Regional Records Center, and by Michael P. Musick who, as always, guided me through the Record Group 77 labyrinth at the National Archives.

This study focuses upon the Davis Island project's technological history because of the character of the records. Its political and economic history is of equal interest, but could not be fully investigated within the six-month time limit placed upon the study, for political conflict took place largely within committees of Congress and the Pennsylvania legislature which at the time maintained few written records and the project's economic and environmental effects were not extensively analyzed in either preauthorization or postauthorization studies. Research into those aspects of the project's history will continue as time permits, and the results will eventually be disclosed in other publications.

Leland R. Johnson

Acknowledgments

The author and the Pittsburgh Engineer District are indebted to the Office of the Chief of Engineers and the Louisville Engineer District for supplying photographs of personnel and project operations. Our thanks also are due to the Carnegie Library of Pittsburgh which furnished most of the photographs of the Davis Island project construction phases.

CONTENTS

INTRODUCTION

Pittsburgh is the greatest inland river port in this country, and one of the greatest in the entire world. In its location at the head of the Ohio River, and in its utilization of unequaled water facilities, Pittsburgh exemplifies more than any other river port the results that we seek in developing and improving our natural river channels.

Raymond A. Wheeler, 1946

Lieutenant General Raymond A. Wheeler, the Chief of Engineers in 1946, described the Pittsburgh, Pennsylvania, harbor as a collective super-plant facility used by the industry around the harbor's perimeter for the exchange of fuels, raw materials, and manufactured products in various processing stages. The Pittsburgh harbor in 1946 had more river bank developments for the discharge, storage, and loading of vessel cargo than any other inland port and it was therefore vital to the national industrial production and distribution system. General Wheeler's observations remained true in 1985, but Pittsburgh has not always enjoyed an uninterrupted waterway transport system. Pittsburgh had no harbor before 1885 when the U. S. Army Corps of Engineers completed the Davis Island Lock and Dam on the Ohio River five miles downstream of the "Point."

At its centennial in 1985, the site of the Davis Island Lock and Dam under the bluff overlooking the Ohio River at Bellevue was quiet. There being no highway access, the site had been largely forgotten. Only by scrambling through brush and weeds could one find the remnants of the lock house foundation, concrete walkways, gate recesses, and retaining wall at the river bank marking the site of one of the most memorable achievements in the annals of international waterway engineering technology.

The planning, construction, and operation of the Davis Island Lock and Dam, the first to be built on the Ohio River, during the

decades following the Civil War presented the Army Engineers with unparalleled engineering challenges. The innovative technology they applied to meet those challenges left indelible marks upon the history of Pittsburgh, the Ohio River, and waterway engineering throughout the United States. At Davis Island in 1885, the Engineers completed the largest Chanoine dam and navigation lock ever built to that date. Its design became the standard at the fifty additional locks and dams built to canalize the Ohio River, first to a six-foot depth and after 1910 to a nine-foot depth from Pittsburgh to Cairo, Illinois. The project's planning and design taxed engineering ingenuity to the utmost, leading to a worldwide search for engineering solutions to the problems presented by inland river navigation and resulting in an international technological exchange which has continued into the 20th century. Its construction required the application of a broad array of technological innovations, and its operation required the adaptation of a variety of experimental water control structures and procedures to meet the demands of a burgeoning waterway commerce.

The origins of the Davis Island project lay in the natural condition of the lower Allegheny, Monongahela, and Ohio rivers, which had such inadequate dry-weather flow that their depth could be measured in inches. During several months in most years, Pittsburgh's steamboats, towboats, and barges remained landlocked, unable to move until it rained and the rivers rose to boatable stages. Pittsburgh's mills during those months sometimes closed for want of raw materials and fuel, commercial shipments piled up at riverside, business languished, and unemployment became the lot of workingmen. Those seasonal economic recessions often extended down the Ohio, for Cincinnati, Louisville, and other downriver cities then depended upon shipments of Pittsburgh coal to fuel their industries.

It was during such a seasonal dry spell and accompanying economic recession in 1871 that Pittsburgh's industrialists and businessmen launched their campaign to secure for the city a reliable harbor with a year-round depth for navigation. Pittsburgh should no longer, proclaimed one local newspaper, be dependent "upon the rain from Heaven for conducting our chief employment." The ironmasters of Pittsburgh also threw their substantial weight behind efforts to secure funding from Congress for the construction of a lock and dam on the Ohio providing Pittsburgh with a harbor and to initiate the building of locks and dams along the entire 981-mile length of the river. But, as odd as it now may seem, rivermen and coal shippers of the Pittsburgh area vigorously opposed locks and dams, fighting the ironmasters over the issue in both the state legislature and Congress. Caught in the middle of that battle between the iron and coal titans of Pittsburgh was Colonel William E. Merrill, the Army Engineer officer in charge of the Ohio River.

Colonel William E. Merrill was the central figure in the history of the planning and construction of the first lock and dam on the Ohio. It was his efforts to placate opposition to the project which made the Davis Island Lock and Dam the experimental station for waterway structural design in the United States. It was his workable search for engineering solutions to the problems he encountered at Davis Island that initiated an international exchange of hydraulic technology which has continued into the 20th century. He personally designed the Davis Island project, building there the largest navigation lock and the largest Chanoine dam of the 19th century by adapting European technology to conditions on the Ohio River.

Intense opposition to the project prevented the start of its construction from 1871 to 1878, and building it required another seven years, 1878 to 1885, as a result of foundation difficulties, flooding, and meager funding. Pittsburgh therefore did not have a harbor until 1885, and a second lock and dam on the Ohio was not completed until 1904 because Colonel Merrill and his successors in charge of the river delayed further work on the Ohio until the operation of the Davis Island Lock and Dam had proven successful and had allayed the opposition of rivermen.

Operating the giant lock and dam at Davis Island, with its many complex mechanisms devised by European engineers and by Merrill and his staff, proved to be a task as formidable as its planning and construction. Its operation revealed many design weaknesses, which Merrill and his successors remedied through the application of technology and improved operational procedures. For thirty-seven years, the engineers and operating personnel at Davis Island made the project work for Pittsburgh, redesigning, rebuilding, and improving parts of the project each year. By the time it was removed to make way for the Emsworth Locks and Dams in 1922 few of the original parts of the structure remained.

Little remained at the Davis Island site in 1985 to testify to the political controversy, the engineering experimentation, and the frenzied activity that had occurred there over a century before; and of the fifty additional locks and dams built along the Ohio from 1885 to 1929 on the pattern established at Davis Island, only two remained in service. Yet, the history of the Davis Island project remains of interest, for it influenced the history of Pittsburgh, the Ohio River valley, and the nation. Except in scale, the engineering achievements at Davis Island have not been surpassed in the 20th century.

I

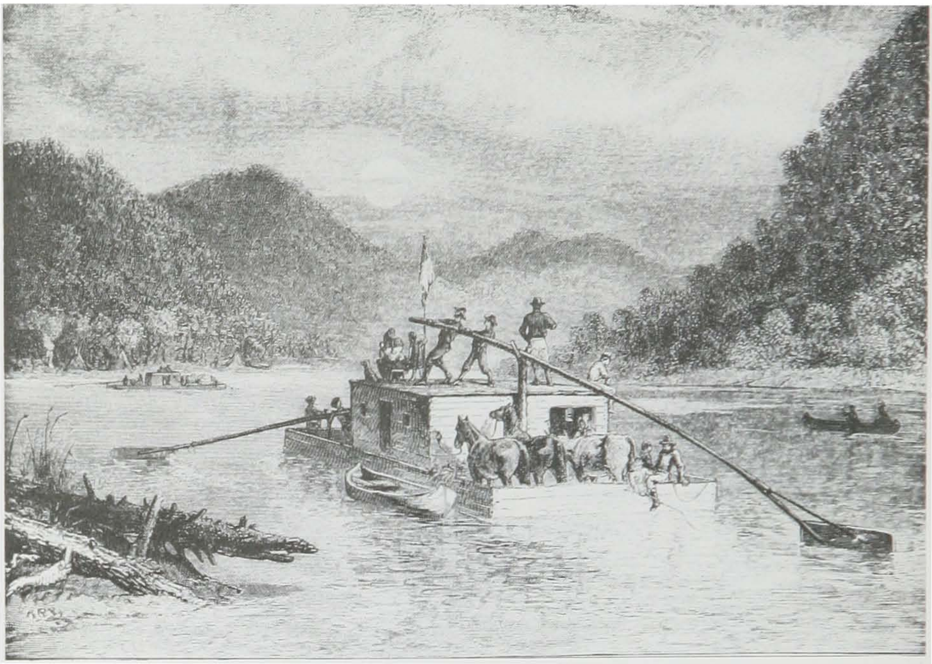
RIPPLES ON THE OHIO

O'er Horsetail when the stream was low,
Wades a bold misguided cow;
False Horsetail! Caverns lurk below
Thy wave, that glitters joyously!

James Hall, 1828

So dreaded were the obstructions along the Upper Ohio River that early boatmen gave each a name and even scribbled doggerel about them. Horsetail Ripple, Cow Island, Glasshouse Ripple, the Trap, Lowrie's Ripple, Merriman's Ripple, and Deadman's Island were some of the names given the obstacles to navigation encountered by boatmen leaving Pittsburgh for downstream ports, and those obstacles often were memorable indeed. "Sometimes we were jostling on the rocks in the ripples," recalled one boatman, and "sometimes we were driven furiously along the chutes, and sometimes we stuck fast on the sandbars." When hardly out of sight of Pittsburgh, luckless boatmen lost all they had when their watercraft rammed into rocks at Cow Island and Horsetail Ripple. Cow Island, located at the head of Horsetail Ripple, was renamed Davis Island in the 19th century after the farmer who grazed his cattle thereon, and it was from his son that the Corps of Engineers in 1878 purchased the head of the island for use in building the first lock and dam on the Ohio.[1]

Planning for the Davis Island Lock and Dam began on the heels of the Civil War and represented the culmination of efforts by Pittsburgh waterway shippers who since 1819 had worked to secure improved transport access to Southern and world markets. Completion of the National Road into Wheeling in 1818 threatened to divert pioneer emigration and river commerce to Wheeling from Pittsburgh, which had long enjoyed the economic advantages accruing from its position as the port of embarkation for the Ohio. As a result, Pittsburghers



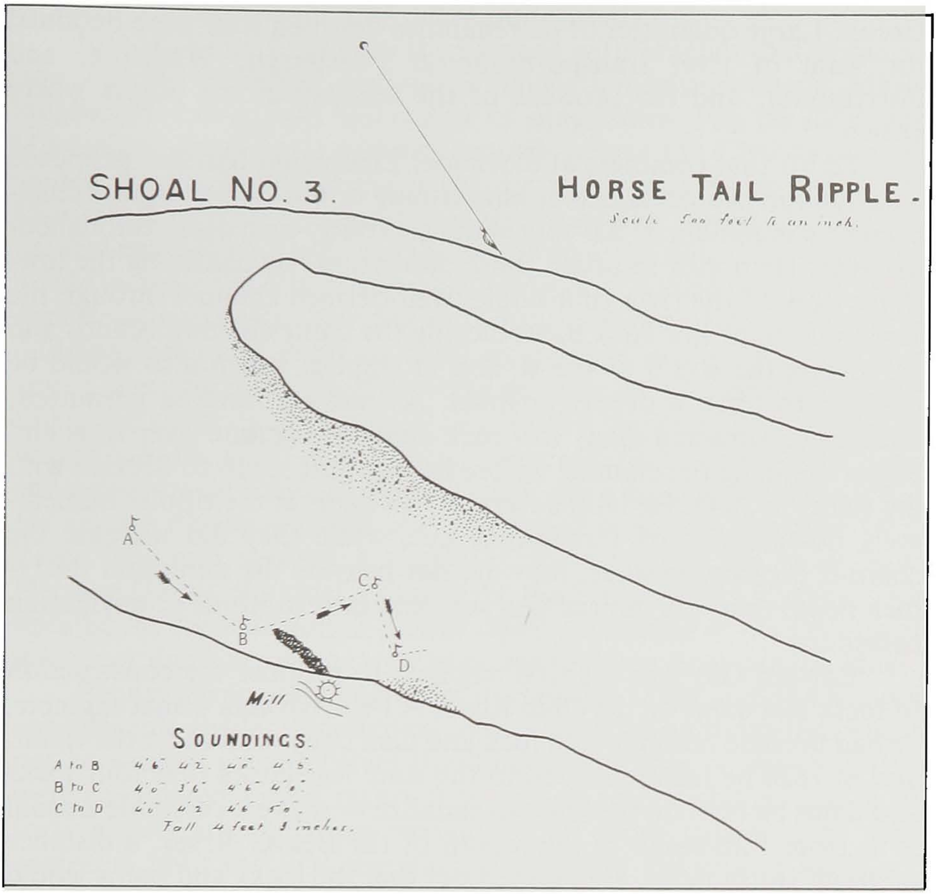
Flatboat pioneers faced navigation hazards at Horsetail Ripple and other obstructions on the Upper Ohio River.

Pittsburgh District

united to clear at their own expense some of the obstructions to navigation from Horsetail Ripple and other hazardous rapids impeding river traffic from Pittsburgh down to Wheeling. Merchants contributed funds and workmen furnished the labor needed to blast jagged rocks out of the channel downstream of the Point where the Allegheny and Monongahela merge to form the Ohio.[2]

When Magnus Murray, an engineer, ironmaster, and subsequently mayor of Pittsburgh, surveyed the obstructions in the Ohio in 1819, he found river flow so negligible that all commerce had stopped, leaving boats stranded on sandbars rotting in the sun and forcing Pittsburgh industry to close with major economic repercussions. So great was public distress that the Commonwealth of Pennsylvania appropriated funds in 1821 to remove more obstructive rocks from the Ohio and to build low rock dams confining river flow to a single and somewhat deeper channel from Pittsburgh to Wheeling.[3]

Other state governments along the Ohio viewed the improvement of its navigation as a federal rather than a state obligation, because it served as the outlet to world markets for several states, and in 1824, chiefly through the influence of Congressman Henry Clay of Kentucky, the Ohio Valley states secured a federal appropriation for clearance of the Ohio's channel and the assignment of the U. S. Army Corps



1819 map of Horsetail Ripple showing a portion of Davis (Cow) Island.

Louisville District, redrawn from a copy

of Engineers to the direction of the clearance project. Starting at Pittsburgh in 1824, the Corps of Engineers undertook to clear the Ohio of snags, giant trees which had fallen into the river from eroded banks, which often pierced the wooden hulls of boats, sending them to the bottom. Captain Henry M. Shreve and Major Stephen H. Long supervised the snag-clearing project for the Army Engineers from offices at Louisville, Kentucky.[4]

Congress in 1835 approved a separate project for the Upper Ohio River and Lieutenant John Sanders, in charge of the office of Ohio River Improvements at Pittsburgh, began a detailed survey of channel conditions. Finding no more than twelve inches of water available in the channel at several points, and river commerce entirely blockaded because of the shallowness of the river, Sanders described the economic impact of that dry channel: "The inconvenience and loss arising from an interrupted navigation of the river has been felt throughout the

Union. Large quantities of merchandise destined west were detained for want of river transportation at Pittsburgh, Wheeling, and Portsmouth, and the produce of the country at the points where grown."[5]

To lift that commercial blockade, Lieutenant Sanders proposed a navigation project aimed at establishing on the Upper Ohio a channel with a minimum of 200-foot width and thirty-inch depth throughout the year. He hoped to attain those dimensions by confining the low-water flow of the river to a single, well-defined channel through the construction of low rock dams closing the chutes behind islands and narrowing the width of the stream at ripples, which also would be dredged to open a deeper channel. As meager funding permitted, Sanders constructed many low rock dams to regulate river flow and began dredging the channel before he was sent south to Mexico with the Army in 1846. He built several of his dams at the ripples immediately downstream of Pittsburgh, but, while they did increase the channel depth somewhat, they did not provide the minimum thirty-inch depth that was desired and seasonal interruptions to navigation continued.[6]

Edward Gay was the first engineer to propose the construction of locks and dams on the Ohio River. A Pennsylvania Canal engineer, he had become familiar with lock and dam construction on the canal, and in 1828 he recommended to the state legislators that four locks and dams be built on the Ohio to canalize — make it resemble a canal — it from Pittsburgh to the mouth of the Beaver River, a distance of about thirty miles. He pointed out that the locks and dams would provide a harbor for Pittsburgh and also connect the terminal of the Pennsylvania Canal at Pittsburgh with the canal running up the Beaver River valley and on to Lake Erie. The state government, however, did not adopt Gay's recommendations.[7]

Captain George W. Hughes, who examined the Ohio from Pittsburgh to Louisville in 1842, became the first Army Engineer to study the creation of slackwater navigation through lock and dam construction on the Ohio. He commented in his report that river navigation improvement was considered "the most difficult problem of solution in the whole science of civil engineering," and he mentioned that the complexities of the problem had resulted in the substitution by English and American engineers of canals for rivers, using rivers merely as feeders for canals. Hughes noted that French engineers had developed new technology during the 1830s to successfully build locks and dams in rivers, thereby forming "une rivière canalizé," and he thought canalization of the Ohio would best serve the needs of commerce on that stream, but he recognized that meager funding available for waterway projects in the United States in 1842 precluded the construction

of locks and dams, for they were quite costly.[8]

Not all Army Engineers then agreed with Hughes that canalization was the preferred method of navigation improvement. Major Stephen H. Long, who had charge of snag removal on the Ohio and Mississippi rivers for a quarter century before the Civil War, contended that locks and dams ought not to be built on the Ohio and Mississippi rivers. He argued that the structures would obstruct the natural navigation on the rivers, would slow the rivers' currents, and would increase the rate of sediment deposition in their channels. Other American engineers, like Major Long, questioned the wisdom of building locks and dams on great rivers such as the Ohio and suggested alternate methods of providing greater channel depths. Charles Ellet, the canal and railroad engineer who designed the suspension bridge over the Ohio at Wheeling, suggested that large storage dams and reservoirs on tributary streams might store flood water in the spring for release during summer and autumn droughts to augment Ohio River flow and thereby maintain a six-foot depth for navigation. Herman Haupt, the chief engineer for the Pennsylvania Railroad, advocated the construction of a canal down the margin of the Ohio, with low check dams across the river at points to divert flow into the canal.[9]

Pennsylvania state engineers during the 1830s and 1840s made considerable strides in designing locks and dams on rivers that would not be washed away by river flooding. Tributaries of the Ohio then were considered a state rather than federal responsibility, and in efforts aimed at improving navigation on those streams, the state engineers built the first successful slackwater systems of locks and dams. During the 1830s the State of Ohio began building locks and dams on the Muskingum River as part of its state canal system, the Commonwealth of Kentucky built locks and dams on the Green and Kentucky rivers as part of its statewide transportation network, and the Monongahela Navigation Company, a private corporation formed in 1836, started the construction of locks and dams to canalize the Monongahela from Pittsburgh upstream to the Pennsylvania-West Virginia state boundary.[10]

The principal engineers on those state and private navigation projects were men who had learned to design and build locks and dams while constructing the Pennsylvania Canal across the Appalachians and into Pittsburgh during the late 1820s and early 1830s. W. Milnor Roberts, who designed the locks and dams on the Monongahela, and General James K. Moorhead, who built them, both learned their trades on the Pennsylvania Canal system. "The first time I saw Old Slackwater," Roberts later recalled when speaking of General Moorhead, "he was standing in a river in water to his neck. I asked if he were not a bit wet, and he replied that while other contractors might go under no river would get the best of him."[11]

General James K. Moorhead, President of the Ohio River Commission, directed efforts by Pittsburgh industrialists to secure federal funding for construction of the Davis Island project.

Carnegie Library of Pittsburgh

General James K. Moorhead, who bore the nickname "Old Slackwater" given him in tribute to his ardent advocacy of that waterway engineering method, became the premier proponent of the Davis Island project on the Ohio after the Civil War. A largely self-trained transportation and communications expert, a wealthy industrialist, and a power in Pennsylvania and national politics, Moorhead [redacted] to Scotch-Irish immigrants. He helped his father operate a ferry on the Susquehanna River, served an apprenticeship to a tanner, and took a job on the Pennsylvania Canal, apparently as a state employee and then as a contractor for its construction. When the canal opened to navigation, he organized a canal boat packet line running into Pittsburgh, where he settled in 1836. He and his brothers became owners of the Soho Iron Mill, the Union Cotton Mill, and other Pittsburgh industries, invested in railroads and steamboats, and organized the company — a predecessor of Western Union — which built telegraph lines from Pittsburgh to Philadelphia and Louisville. The source of their venture capital is not made clear in available records, but no doubt the marriage of William Moorhead, a brother of James, to the sister of Jay Cooke and his subsequent executive leadership of the famous Jay Cooke banking house proved advantageous. Active in politics, James K. Moorhead served briefly as Pennsylvania

Adjutant-General, as the Pittsburgh Postmaster, and in 1858 was elected to Congress.[12]

When the Monongahela Navigation Company bankrupted in 1841, General Moorhead accepted worthless company stock as payment for his services to the company as construction contractor and with his own capital resumed the construction of locks and dams, opening slackwater navigation into Brownsville in 1844. The tolls collected from heavy shipments of coal through the locks and dams to Pittsburgh and on down the rivers as far as New Orleans made stock in the Monongahela Navigation Company gilt-edged, paying a ten percent annual dividend. In sum, everything General Moorhead touched seemed to succeed and turn to gold.[13]

Having completed the Monongahela navigation project largely through his personal initiative, General Moorhead in 1855 turned his attention to the Ohio River and interested the Pittsburgh Board of Trade in the subject. Interesting the Board of Trade in the Ohio was not difficult, for in 1854 an extended drought had interrupted river commerce for months. A newspaper editor who was a member of the Board of Trade at the time wrote:

> Much inconvenience is experienced at Pittsburgh for want of greater depth of water during most of the year. The channel of the Monongahela along the levee has a pretty good depth, but it is narrow during low water. The Allegheny is full of shoals and the current strong — too strong for the advantageous use of towboats. A dam that would raise the water eight foot at McKee's Rocks, two miles below the city, would swell it at least six feet on both sides of the city, backing the Monongahela against Dam No. 1 of the slackwater, and rendering the Allegheny a slackwater of good depth to some distance above Sharpsburg. What a magnificent harbor for the commerce of the three rivers would such a pool afford? It would be worth more to that city than would pay for three such dams.[14]

General Moorhead and the Pittsburgh Board of Trade in 1855 took interest in the river engineering methods advocated by Herman Haupt, rather than lock and dam construction. The influential chief engineer of the Pennsylvania Railroad proposed building a canal down the Ohio, with occasional check dams diverting river flow into the canal and thereby avoiding the obstruction of the river channel by fixed dams of the sort built on the Monongahela. Haupt formed an Ohio River Improvement Company with a directorship including General Moorhead, former Secretary of War William Wilkins, President John Edgar Thomson of the Pennsylvania Railroad, and attorney Edwin M. Stanton, soon to become Lincoln's Secretary of War. The company hoped to secure federal assistance similar to the grants

Congress had made to the Illinois Central and other railroads for the costs of construction and to profit from the collection of tolls from boat traffic as had proven so profitable on the Monongahela. "Experience has taught us that public works, under National or State management, are not only unprofitable, but demoralizing and dangerous," wrote one proponent of the company's plans, adding: "Far better that the work should be done solely by individual effort, than that it should become an arena for the struggles and trickery of politicians and place-hunters."[15]

Congress proved unwilling, however, to grant a river navigation company the funding assistance it had given to railroad corporations. A Senate committee declared that the Ohio River Improvement Company had a charter only from Pennsylvania, while the river flowed through several other states. It therefore quashed the company's hopes with the proclamation that: "The Ohio is a national highway, and no single State can claim jurisdiction over it, or pretend to the right to disturb the flow of its waters, to regulate the transportation or tax the commerce that floats on its surface."[16]

The controversies concerning the proper means of improving navigation on the Ohio River ended temporarily at the onset of the Civil War as the participants turned to more pressing matters of national defense. General Moorhead served as Pittsburgh's "war congressman." A founder of the Republican Party in Pennsylvania, he became a personal political advisor to President Abraham Lincoln and subsequently to James G. Blaine, James Garfield, and William McKinley, all of whom stayed at Moorhead's home when visiting Pittsburgh. Though heavily involved in the prosecution of the Civil War, he did not neglect Pittsburgh's other interests, and in 1864 he sent to the House Committee on Naval Affairs a report urging that Congress act to secure the permanent improvement of Ohio River navigation. Mentioning the large appropriations Congress was making for the construction of the transcontinental railroads, the report argued that Ohio River navigation was equally deserving of significant federal assistance. It pointed out that the Navy was paying high prices to supply the Mississippi River squadron of gunboats with coal and contended that those prices resulted from the lengthy low water stages on the Ohio which prevented the shipment of Pittsburgh coal downriver during several months of each year.[17]

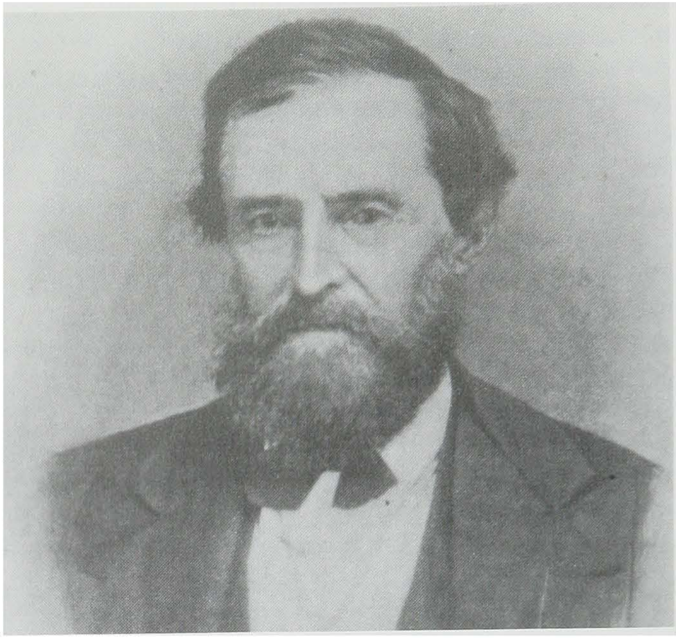
Coal barges required a minimum depth of six feet to navigate the Ohio; yet, the river at Pittsburgh was less than three feet deep during 22 percent of each year, between three and six feet deep 35 percent of each year, and over six feet deep only 43 percent of each year on the average. Coal shipments therefore could descend the Ohio during less than half of the year on the average. Extended low water

stages not only increased coal prices but also deprived the industries of Cincinnati, Louisville, and other downriver ports of the fuel needed to manufacture military supplies for the Union armies. While he and his company had improved Monongahela navigation with private venture capital, General Moorhead concluded that could not be done on the Ohio River, where "if done at all, it must be done by the General Government."[18]

As a national political arbiter and as close friend of Edwin M. Stanton, the Secretary of War to Presidents Abraham Lincoln and Andrew Johnson, General Moorhead was in position at the close of the Civil War to secure action on the Ohio River navigation problem. When Congress in 1866 embarked on a major postwar program for the improvement and development of the nation's waterways, Moorhead obtained through Secretary Stanton the appointment of W. Milnor Roberts, his old associate in planning the Monongahela River project, as the U.S. Civil Engineer in charge of the Ohio River.[19]

After leaving the Monongahela project, W. Milnor Roberts served as chief engineer on a number of canal and railroad projects, working for a time as the head of public works in Brazil and earning an enviable reputation for his engineering expertise. He had used that reputation in 1857 to quash the plans laid by Charles Ellet for the improvement of Ohio River navigation through the construction of dams and reservoirs on tributaries to store flood water for release during droughts. When Congress in 1857 seemed on the verge of funding surveys of the reservoirs Ellet proposed, Roberts published a critique of the scheme, contending that its engineering and construction would prove far more complex than Ellet had imagined and arguing that Ellet had not fully considered the great costs of relocating towns and railroads to make way for the reservoirs. He urged that a slackwater system of the sort already in successful use on the Monongahela would cost much less than Ellet's reservoirs, would produce immediate results, and was an established rather than experimental waterway engineering technology.[20]

Assisted by his son Thomas P. Roberts and George Rowley, a famed keelboat and steamboat captain, W. Milnor Roberts in 1866 resumed the prewar channel clearance project on the Ohio, awarding contracts to remove accumulated snags and to rebuild the low rock dams behind islands. As directed by Congress, he also conducted a survey of the Ohio to plan its "radical" and permanent improvement for navigation. Starting at Pittsburgh, he learned that 301 steamboats with an aggregate of 77,789 registered tonnage had been built there during the Civil War and that the city had 11 shipyards employing 500 men, 24 machine shops which fabricated steamboat engines, 12 plants which manufactured boilers, and 10 forges making chains and



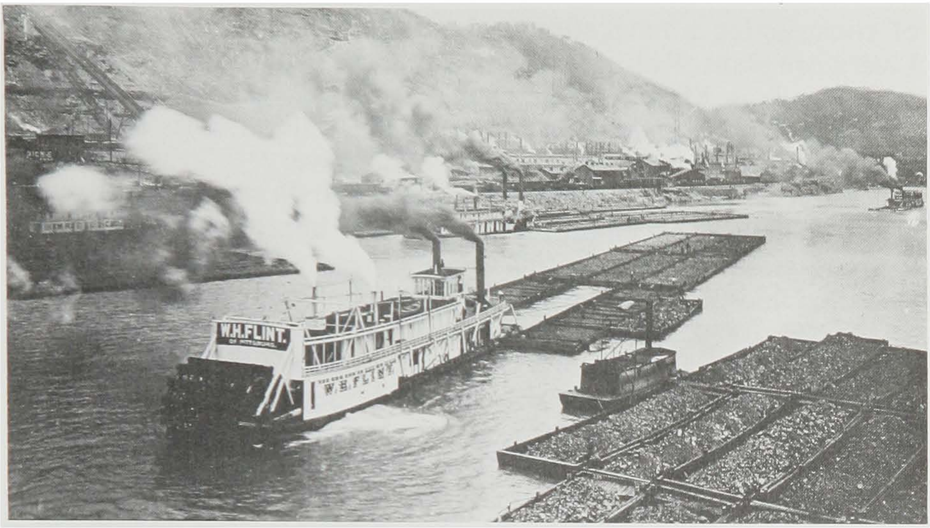
William Milnor Roberts in 1870 proposed the "radical" improvement of the Ohio River through the construction of locks and dams.

MG Milnor Roberts

boat ironwork. Because the annual value of Pittsburgh manufactures amounted to $80 million, he declared there seemed no limit "to the future manufacturing and commercial greatness of this favored point. Nature has done all that any city could ask; enterprise has already effected very much, and future enterprise will effect much more."[21]

The steamboats built at Pittsburgh included what are called towboats, though they pushed rather than towed barges. About 7,000 miners along the Monongahela in 1866 produced 2.5 million tons of coal, of which about two-thirds went downriver in 1,500 barges pushed by 98 steam towboats. Oil from up the Allegheny and iron manufactured at Pittsburgh, Steubenville, and Wheeling also went to market down the Ohio in barges. W. Milnor Roberts predicted that the historic steamboat packet trade on the Ohio would eventually decline and "the bulk of freighting will probably be ultimately carried on by means of barges towed by steamers."[22]

The barge towing system on the Ohio had begun in 1854 and by 1866 people gathered at riverside below Pittsburgh to see the huge barge tows glide past. When markers indicated a seven-foot river stage had drowned Glasshouse and Horsetail ripples near Davis Island, the tows departed Pittsburgh in a rush, one behind another, to avoid losing the rise and stranding when the river receded. Through the narrow



When the Ohio River reached a seven-foot stage at Glasshouse Ripple, the Pittsburgh coal fleet departed for the downstream markets.

Pittsburgh District

chutes, around sharp bends, threading between bridge piers as through the eye of a needle, the towboat pilots guided the massive island of coal on the barges before them, backing, flanking, or pushing the barges like the tail wagging the dog before it.[23]

During dry weather, hundreds of coal barges and dozens of towboats gathered in the pool upstream of Monongahela River Lock and Dam 1 to await a seven-foot rise on the Ohio before departing for Southern markets, and all wished to pass the lock at once to get on their way before the rise ended. Because passing so many craft through Lock 1 took days, and some boats therefore lost the rise, General James K. Moorhead and his navigation company were interested in building a chute through the dam. The chute, or opening through the crest of the dam, would be closed by movable gates to hold the pool; and at the departure of the coal fleet the gates would be lowered or removed, allowing the barges to rush through the gap in the dam and bypass the lock.[24]

W. Milnor Roberts studied movable gates and chutes for dams and was impressed by the plans of Alonzo Livermore, who had worked with him on the Pennsylvania Canal and who he had employed to assist with the Ohio River survey. Livermore's plans called for cutting a gap in a dam, closing it with movable timber shutters, and building a slope on the downstream side of the dam for barges to glide down to the channel below. The plans somewhat resembled the chute arrangement in mill dams on streams in Kentucky where the owners passed flatboats through chutes in their dams instead of going to the expense

of constructing a navigation lock. Rather than recommending the Livermore plans, Roberts suggested that the Chief of Engineers fund experiments at Monongahela Dam 1, cutting a gap in the dam and installing movable gates to determine their effectiveness, for such chutes might also be used at dams on the Ohio River.[25]

After a three-year study of the Ohio and its commerce, Roberts in 1870 submitted his report on the "radical" improvement of the river for navigation. Again rejecting the Ellet reservoir plan, he proposed that the Ohio be canalized to a six-foot depth through construction of sixty-six dams, each with two locks, one 80 by 370 feet and the other 60 by 300 feet, in order that one lock could remain open to navigation while the other was repaired. Because locks with those dimensions were too small for coal barge tows, he suggested the installation of a chute in each dam to pass tows without lockage, the type of movable gate to close the chutes to be determined through experiments at Dam 1 on the Monongahela. He recommended that the construction of locks and dams should start with one near McKee's Rocks, three miles downstream of the Point. Though heartily endorsing locks and dams and slackwater navigation as the best means of accomplishing the "radical" improvement of navigation on the Ohio, he warned that further planning was needed and that strenuous public objections would be made to the project, philosophically concluding: "No great scheme designed for general public benefit ever yet escaped objections of some sort."[26]

His mission accomplished, Roberts resigned from government service to help James Eads build a bridge over the Mississippi at St. Louis. He and his son Thomas subsequently rode muleback over the Rockies in 1872 to select the route of the Northern Pacific Railroad, and in 1878 he became president of the American Society of Civil Engineers. Thomas P. Roberts settled at Pittsburgh as chief engineer of the Monongahela Navigation Company for General Moorhead and, from 1897 to 1923, as senior engineer in the Pittsburgh Engineer District.[27]

II

RADICAL PLANNING STUDIES

The great advantages of the slackwater plan are that it is simple; its expense can be calculated with as much accuracy as any work in water can be, and I think I ought to state here that any work in water is subject to contingencies which cannot be foreseen, and therefore exact estimates are simply impossible. A bed of a stream is itself your reservoir, and it gives all the water you need, and not one drop more. You simply retain what is needed for navigation.

William E. Merrill, 1874

The successor to W. Milnor Roberts at Pittsburgh in charge of the Ohio River was to remain in charge of projects on that stream some twenty-four years and earn the sobriquet "Father of the Ohio River Improvement." Tops in the Class of 1859 at West Point, William E. Merrill, because of his brutal honesty and fondness for foreign languages, was known to his classmates as the "Padre." While on reconnaissance for the army during the Civil War he was wounded and captured, and after his exchange, as chief engineer of the Union Army of the Cumberland, he devised improved pontoon bridges, better railroad defenses, and faster map-production methods, contributing in no small measure to Union victory in the West and earning the brevet rank of colonel. Though reverting to the rank of major of Engineers after the war, he was addressed thereafter as colonel, and on the Ohio River he was *the* Colonel, a fatherly figure who trained such junior officers as Frederick A. Mahan, William M. Black, and George W. Goethals in the complexities of waterway project engineering and administration. Sent to the Upper Mississippi River project after the war, he studied railroad bridge construction and in 1870 published a monumental engineering analysis of bridge trusses. That knowledge

and his fondness for foreign languages proved useful during the planning studies for the "radical" improvement of the Ohio and earned him a reputation as one of the foremost waterway engineers of the 19th century.[1]

Reporting to Pittsburgh in June 1870, Merrill found considerable work in progress along the Ohio. Responsible not only for the Ohio near Pittsburgh but also for its entire 981-mile length and several of its tributaries, he moved his office from Pittsburgh to a more central location at Cincinnati in 1871 to reduce travel costs. Though constantly on the move from one end of the river to the other, Merrill had an indomitable energy that permitted him to accomplish staggering amounts of work. In 1870 he initiated efforts to secure adequate authority and funding for constructing an Engineer snagging and dredging fleet, for marking the river channel, and for a beginning on the "radical" and permanent improvement of the Ohio's navigation. Within six years, he had accomplished all those goals.[2]

Securing funding for an Engineer snagging and dredging fleet in 1872, he built the dipper dredges *Ohio* and *Oswego* and the snagboat *E. A. Woodruff.* All patrolled the Ohio during the following half century, removing snags, cutting channels through sandbars, and assisting at dam construction projects, and all outlasted their builder: the *Oswego,* for instance, was still afloat in 1985 after more than a century of service. In his first report to Congress, Merrill recommended that Congress fund the lighting and buoying of the channel to mark it for both day and night navigation, and in 1874 Congress established a lighthouse district for the inland rivers which installed the navigation aids, saving countless boats and lives during the ensuing century.[3]

Though engaged in a whirlwind campaign to clear and improve the entire channel through river regulation engineering, Merrill's attention was increasingly drawn to Pittsburgh where W. Milnor Roberts' 1870 report proposing the construction of locks and dams on the Ohio had unleashed a storm of controversy. General James K. Moorhead was organizing Pittsburgh industrialists and businessmen for a lobbying effort on behalf of the slackwater project recommended by Roberts, while, ironic as it may now seem, rivermen and coal shippers organized to thwart Moorhead's efforts. Not willing and not bound to accept Roberts' recommendations without question, Merrill reopened the investigation, reviewing the plans proposed by Charles Ellet, Herman Haupt, and Benjamin S. Roberts.

Charles Ellet died in 1862 from wounds received as commander of a Union gunboat at the Battle of Memphis, but his concept of building dams and reservoirs on tributary streams to store flood water for subsequent release to augment Ohio River flow during droughts still had support. It had the advantage that it might provide a minimum

six-foot depth on the Ohio without obstructing the stream with locks and dams. Noting that engineering knowledge of the construction of large dams and reservoirs was inadequate at the time and that the costs of building such structures would be very high, Merrill concluded that use of the Ellet scheme for the improvement of Ohio River navigation would be an "enormously costly experiment."[4]

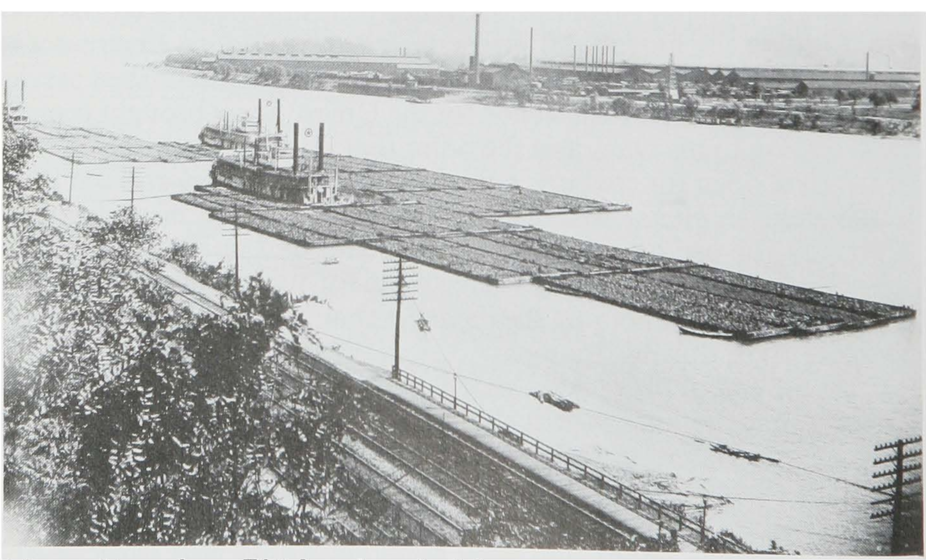
Yale University professor Benjamin S. Roberts suggested that water might be pumped from the Great Lakes and sent down the Allegheny or Beaver rivers to augment Ohio River flow, thus achieving Ellet's goal without building dams and reservoirs. Drawing on his experience as a Union Army general, Benjamin Roberts argued that it was the destruction of Southern railroads which had brought the Confederacy to its knees and warned that all railroads in the United States were similarly vulnerable to enemy attack and sabotage. "But navigable rivers and lakes cannot be destroyed, and they must become our main reliance as an invulnerable military power," he observed, while pointing out that the costs of pumping water from the Great Lakes to the Ohio would be negligible in comparison to the defense values accruing from inland rivers that were navigable the year round. Merrill estimated, however, that the cost of a pumping system adequate to move sufficient water from the Great Lakes over the divide into the Ohio River basin would total $625 million, plus annual operating costs of $125 million, and he rejected that "extravagant" plan.[5]

Herman Haupt had proposed in 1855 building a canal alongside the Ohio to carry boats when the river was low, leaving the open channel for coal tow navigation at higher river stages, and he found support for his plan in Pittsburgh. He renewed his proposal after the Civil War, adding the movable shutters designed by Alonzo Livermore to his plan to provide slackwater in the canal. His distinguished service as Director of Military Railroads for the Union Army brought respectful attention to his plan, and the point that it would leave the channel of the river open for coal tow navigation garnered support from Pittsburgh coal shippers. Merrill gave the plan serious consideration, especially for use on the Ohio downstream of Louisville where the stream gradient was less, but rejected it for use on the Upper Ohio for several reasons, notably the damages that would be done to a canal near the river during flooding.[6]

At the end of his review, Merrill finally concurred with W. Milnor Roberts that the only practical plan of "radical" improvement was a slackwater system of locks and dams similar to the systems already operating successfully on the Monongahela and other tributary streams. Those projects and the thirty years of experience with their operations seemed adequate proof that such a system would also work on the Ohio. Land acquisition costs would be minimal because the low dams

of slackwater systems inundated few bottomlands, the engineering and construction technology for such projects was well known, and the dams could be located below each major port on the river, creating excellent harbors for each city.[7]

While the review of planning studies was underway, Pittsburgh was beset in 1871 by an economic crisis of major proportions. The Ohio fell below boating stage in May 1871, not to rise again until the following winter, and by October Pittsburghers were praying for rain. Some ten million bushels of coal were afloat in barges on the pools upstream of Dam 1 on the Monongahela, awaiting a rise to depart downriver, tying up large amounts of Pittsburgh capital while fuel shortages afflicted the industries at Cincinnati, Louisville, Evansville, Paducah, and other downstream ports. Because boats on the pool of Monongahela Dam 1 could not leave that pool to reach the wharf at Pittsburgh or to ascend the Allegheny River, the industry located on Pittsburgh's north side had to secure fuel by wagoning it from the Monongahela across the Point and through the Triangle, causing immense traffic jams and destroying city streets in the process. A Pittsburgh newspaper termed the situation intolerable and demanded that some agency, no matter whether federal, state, or local, had to build a dam on the Ohio downstream of the Point to get the heavily laden coal wagons off the city streets. "Let us no longer depend upon the rain from Heaven for conducting our chief employment," the newspaper implored.[8]



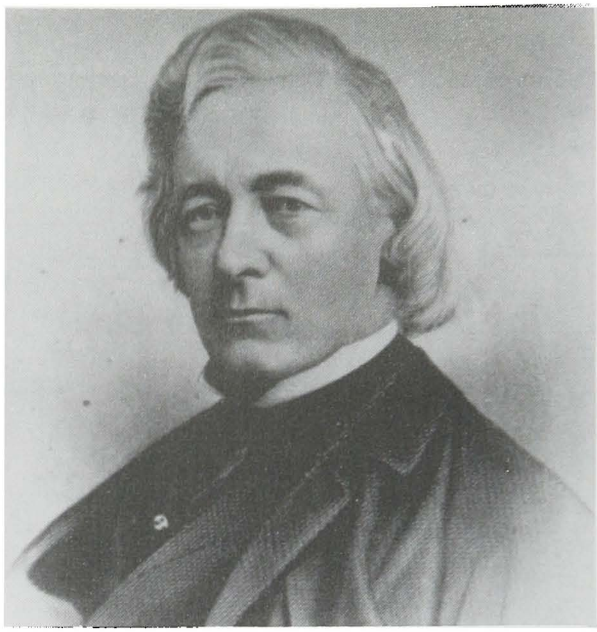
The coaltows from Pittsburgh rushed downriver to avoid losing the rise and stranding on a shoal.

Pittsburgh District

The ironmasters and businessmen of Pittsburgh met in late October and drew up a petition addressed to Colonel Merrill and endorsed by about ninety firms including many marine insurance companies and the Jones and Laughlin, Oliver and Phillips, and Moorhead ironworks. The petitioners contended that, in addition to the destruction done to city streets by coal wagons, the damages resulting from the lack of adequate harbor facilities included depreciation and heavy losses among the coal fleet waiting above Dam 1 on the Monongahela. They warned that if a fire began on one boat the entire fleet would go up in flames. Mentioning that Congress in the previous five years had appropriated $825,000 for improvement of the harbor at Boston, $760,000 for New York, $160,000 for Milwaukee, and $155,000 for Portland, the petitioners asserted that the Pittsburgh harbor was no less deserving of federal largess. To facilitate navigation on the lower Allegheny and Monongahela while covering some "very bad bars" on the Ohio, the petitioners asked that Congress fund the construction of the first lock and dam on the Ohio in the vicinity of McKee's Rocks, which Milnor Roberts had estimated would cost $334,000.[9]

After receiving that petition, Colonel Merrill asked those who opposed the lock and dam to state their case and got his answer in short order. Coal shippers and rivermen met in November and drew up their own petition, signed by seventy-five boat captains and shipping firms, the number including such distinguished rivermen as William H. Brown, John O'Neil, Samuel Cable, and Thomas Fawcett. A lock and dam on the Ohio would ruin their business, they averred, for "coalboat rises" lasted no longer than three days and it would be impossible to get more than a third of the coal fleet through the lock in that time. To avoid the congestion at Lock 1 on the Monongahela, many coal shippers had leased landings along the Ohio as far downstream as Davis Island at the head of Horsetail Ripple where they moored their barges to await a rise. A lock and dam on the Ohio would destroy the moorage facilities along that section of the Ohio, and the ripples and rapids below Davis Island left no room for moorage.[10]

To better understand the objections of coal shippers, Colonel Merrill took passage aboard a coal tow for a trip downriver. The towboat was pushing ten barges and three flats loaded with 130,000 bushels, or roughly 40,000 tons, of coal, and Merrill noted that the same cargo carried by rail would have required a train that was 464 rail cars long. A complex system of cables and chains pulled taut with screw ratchets bound the barges together to form the tow, and Merrill learned what an arduous and dangerous job it was to separate and reassemble the tow and why rivermen opposed the building of locks and dams that would force them to "break tow" for passage. To meet the needs of coal shippers, it would be necessary to install in each dam on the Ohio a chute closed by some form of movable gate which could



Felix R. Brunot, Pittsburgh engineer and philanthropist, invented a hydraulic gate in 1867 which the Army Engineers considered for use on the Ohio River.
Carnegie Library of Pittsburgh

be lowered to open a channel through the dam at higher water stages.[11]

Pittsburgh ironmasters and businessmen met again after the coal shippers had filed a counter-petition to organize as a lobby for the funding of the harbor improvement. As chairman, they selected Felix R. Brunot, a noted engineer, industrialist, and philanthropist. Grandson of the French emigrant who settled on Brunot Island, the first island on the Ohio a short distance upstream of Davis Island, and the son of an Army officer stationed at the Allegheny Arsenal, Felix R. Brunot had begun his career as an engineer on the Pennsylvania Canal and the Monongahela in association with General Moorhead. Earning a fortune through investments in grain and iron mills, he had become a director of the Monongahela Navigation Company, but he is best remembered in Pittsburgh as organizer of medical services for the Union Army, taking caravans of nurses and physicians to the battlefields, on one of which he was captured and interned at Libby Prison in Richmond.[12]

Brunot and General Moorhead contacted Congressman James S. Negley, Moorhead's handpicked successor as the representative from Pittsburgh, and explained to him what they wished. Negley in late 1871 asked the Chief of Engineers to supply him with all available information about planning for the Ohio River canalization and told the

Chief he intended to press immediately for funding of the "radical" improvement of Ohio River navigation, starting at Pittsburgh. As promised, Negley introduced bill after bill in Congress during the next three years to fund the construction of a lock and dam below Pittsburgh.[13]

In January 1872, Merrill forwarded the opposing petitions to the Chief of Engineers together with his analysis of the situation. Noting that the rivers trifurcating Pittsburgh were nearly useless during several months of each year because of their very low flow, Merrill declared: "If a navigable stage of water could be maintained at all times it would greatly facilitate the transfer of the heavy products of the Pittsburgh iron mills, foundries, and refineries, and thus reduce the cost of those products of this great industrial center which enter so largely into general consumption. In the city itself, it would have the additional effect of diminishing a class of street traffic which is annoying to residents, destructive to pavements and very expensive." He recommended that the construction of a lock and dam to improve the harbor be authorized, but warned it was *sine qua non* to coal shippers that the dam have a chute at least three hundred feet wide to allow the passage of coal tows without lockage. Because engineering knowledge of chutes with movable gates was limited, he suggested that the project be considered experimental. It was his opinion, however, that locks and dams should be built at least as far down the Ohio as Wheeling, providing slackwater on that part of the Ohio where its gradient was greatest.[14]

Contacting business associations at other port cities along the Ohio, Brunot and Moorhead arranged the meeting of an Ohio River Improvement Convention at Cincinnati in February 1872. That convention elected Thomas Power of Pittsburgh as its chairman and heard Colonel Merrill describe the plans for improving the river's navigation permanently. The convention resolved that a board of engineer officers should be appointed to study waterway engineering in the United States and Europe and that the governors of the seven states represented at the convention should each appoint five delegates, or a total of thirty-five members, to form an Ohio River Commission charged with looking after the improvement of the Ohio and its tributaries for navigation.[15]

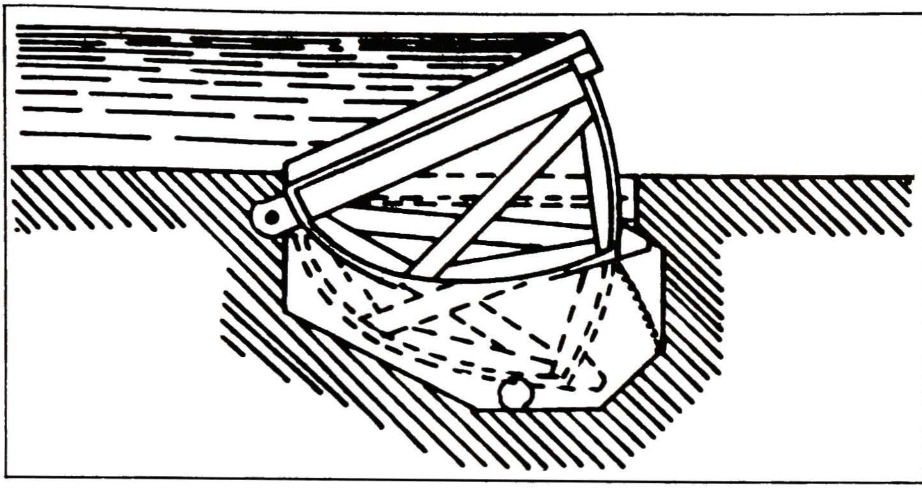
As requested by the convention, the governors appointed the members of the Ohio River Commission, which first met in September 1872 and elected James K. "Old Slackwater" Moorhead as its chairman. In a memorial presented to Congress, the Commission complained that the government had neglected the needs of the inland rivers in comparison with the assistance provided to coastal harbors and the largess handed to railroads. After describing the resources and wealth, the economic and political power of the Ohio River basin, and em-

phasizing its needs for improved waterway transport, the Commission urged Congress to appropriate $2 million to fund further planning studies and to initiate construction of the first experimental lock and dam at Pittsburgh. "When the Government shall have provided the means, the skill of the engineer corps of the United States will find a satisfactory plan beyond a doubt," proclaimed the Commission, adding: "The question is not one of engineering, but of finance."[16]

The Chief of Engineers in the spring of 1872 appointed Colonel Merrill and General Godfrey Weitzel as a Board to examine the hydraulic gates for dam chutes invented by Felix R. Brunot and to report upon their potential use on the Ohio. Weitzel was then stationed at the Louisville and Portland Canal around the Falls of the Ohio, where he was building the largest locks ever constructed. A Cincinnati Rhinelander, he had risen to the rank of major general during the Civil War and had commanded the troops which first entered Richmond in 1865. Returning to the Corps of Engineers after the war, he was assigned to Louisville to build new locks that were seventy-eight feet wide. The widest locks in the world at the time were the seventy-six foot locks at Bremerhaven, Germany, and having a native command of the language, Weitzel translated German engineering publications concerning waterway engineering and used the information in the design of the Louisville lock gates. When the locks at Louisville were completed in early 1872, Weitzel became the nation's recognized expert on lock and lock gate construction.[17]

Weitzel and Merrill requested Felix R. Brunot of Pittsburgh to appear before the Board at Cincinnati to present the hydraulic gate he had invented to close chutes in dams. General Moorhead privately informed them that Brunot would never appear before them, explaining that he was a gentleman of great wealth who devoted his life to philanthropy and would not condescend to peddle his invention before any Army board, nor would he accept compensation for its use if it were adopted. If they wished to see Brunot's drawings and model of his gate, they would perforce come to Pittsburgh. That being the case, Weitzel and Merrill traveled to Pittsburgh, and because other inventors were anxious for the Board to examine the hydraulic gates they had devised, the Board also asked and received authority from the Chief of Engineers to expand their studies to include all types of gates.[18]

After seeing steamboats cross Monongahela Dam 1 at high water stages in 1867, Brunot had been inspired to the invention of a movable hydraulic gate for use in the crest of dams. Composed of a caisson or tank which would sink when water was piped into it and rise when water was pumped out, the Brunot gate could be installed in a gap or chute cut into the crest of a dam. When empty of water the tanks would rise, fill the gap, and hold a pool upstream of the dam; at flood



The Brunot hydraulic gate rose to hold a pool of slackwater, as shown in this diagram, and could descend into a recess to allow boats to pass over it.

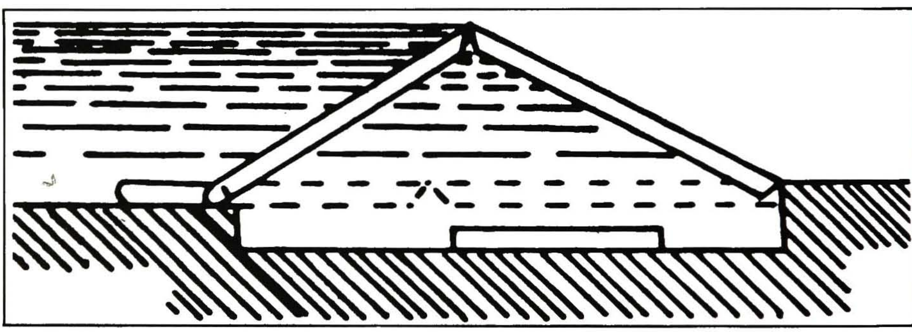
Pittsburgh District

time, the caissons when filled with water would sink to open a clear passage through the dam without lockage. General Moorhead was quite excited about his friend Brunot's concept and urged the board to recommend a full scale trial of the caisson gate in Monongahela Dam 1, with the company paying half the $80,000 estimated cost of the experiment and the federal government paying the other half. If successful, the Brunot gate would alleviate traffic congestion at Lock 1 on the Monongahela and also prove itself for use at the dams to be built on the Ohio. Thinking that proposal would be welcomed, General Moorhead proceeded to build guide walls upstream of Dam 1 to direct boats to the point where the gap would be cut into the dam. The Chief of Engineers, however, could not act without authority and funding for the experiment from Congress, which was not forthcoming, and Weitzel and Merrill therefore continued their studies of gates to close chutes in dams.[19]

Traveling to the Susquehanna River, Weitzel and Merrill saw dams with chutes and movable gates in actual operation. Built by the famed lumberjack John DuBois, the dams on the Susquehanna created artificial rises to float log rafts downriver and had chutes closed by movable gates called "beartraps." Invented by Josiah White on the Lehigh River in 1818, beartrap gates were so named because they somewhat resembled dead falls built by pioneers to trap wild game. The beartraps consisted of two leaves, or rectangular wooden panels resembling very large house doors, which hinged to the bottom of the chute in such a fashion that the upstream leaf lay atop the downstream leaf. By opening a valve to allow water from upstream to flow through a pipe to an outlet under the beartrap leaves, the beartrap could be

made to rise with one leaf propping the other in upright position, thus blocking the chute and holding a pool upstream of the dam. When the valve was closed, the beartrap leaves collapsed to lie flat on the bottom of the chute as water from the upstream pool flushed through the chute and log rafts passed through the dam. Gliding down a slope to the river channel below, the rafts rode the artificial wave released from the pool on downriver to the saw mills.[20]

Lumberman John DuBois made and patented minor improvements to the beartrap design, but they still functioned much like those built on the Lehigh River in 1818. DuBois was interested in the use of his patented beartrap gate on the Ohio, and Merrill and Weitzel built and tested models of beartrap gates. The Board did not think the DuBois beartrap suitable for use at Ohio River dams for the passage of coal tows, for the gates would have to be at least 300 feet wide and water rushing through the beartrap chutes would cause considerable turbulence below the dam. DuBois did persuade General Moorhead to try one of his beartraps in Monongahela Dam 1, where it failed to serve the desired purpose.[21]



Pennsylvania lumberman John DuBois invented a beartrap gate that could be raised with water pressure to hold a slackwater pool as shown in the diagram and could be lowered to allow boats to cross over it.

Pittsburgh District

The Board tested models of four other hydraulic gate systems devised by American inventors. Civil engineer H. Werner and steamboat captain John A. Wood submitted modified beartrap gate plans. Sylvanus Petitdidier and Philip J. Schopp, who were assistant engineers on the Monongahela River project, also submitted gate plans. Petitdidier's device consisted of a wooden panel between piers that was raised and lowered with chains and winches, while Schopp had a caisson gate somewhat resembling that devised by Brunot. The Board also examined a substitute for lock gates invented by Martin Bishop of Ohio, which was composed of a cylinder resembling an elongated barrel that rolled up and down between piers.[22]

Because the Corps of Engineers then had no hydraulic model testing facility like that built in 1929 at Vicksburg, Mississippi, the Board tested the models of movable gates at Pittsburgh, and the models stimulated lively public interest when displayed at the annual civic fair then held in the city. At the end of the testing, however, Weitzel and Merrill determined that none of the devices submitted by American engineers promised to serve satisfactorily to close the 300-foot chutes proposed for Ohio River dams.[23]

While the model testing was in progress, Colonel Merrill put his fondness for foreign languages to good use, reviewing and translating European engineering publications. He was delighted to learn that European engineers had been conducting experiments and building movable dams for many years. "It is of the highest importance that we should avail ourselves of this knowledge and experience," he declared, "and thus save the costly experiments by which it has been obtained."[24]

By mid-1874, Merrill's planning for the first lock and dam on the Ohio had begun to coalesce. He had eliminated alternate plans for the "radical" improvement of the Ohio and had settled upon the slackwater plan advocated by W. Milnor Roberts. It had become clear to him that the lock would have to be among the largest ever constructed in order to handle as many barges as possible in a single lockage, and he had recognized that the project might never be constructed unless some device were located that would permit opening a channel through the dam for the passage of coal tows without lockage. He and Weitzel had, through extensive model testing, eliminated from consideration all the movable, hydraulic gates invented by American engineers, for none seemed capable of closing a chute in a dam that was to be at least 300 feet wide. The foreign languages he had learned at West Point enabled him to begin a review of European engineering publications, and in that literature he found what he thought to be potential solutions for the engineering challenge presented by the problems of Ohio River navigation.

III

INTERNATIONAL PLANNING STUDIES

Money expended in transportation is practically money wasted, inasmuch as it adds nothing to the intrinsic value of the thing transported. It is a waste that can never be wholly avoided, but nevertheless it is a waste, and every consideration for national welfare calls upon us to reduce it to the minimum, every such reduction being a practical addition to national wealth.

William E. Merrill, 1885

Colonel Merrill with equal propriety could have argued that transportation is everything, for commodities have little value if they cannot be transported to markets at reasonable cost. Efforts to develop a waterway transport network to move the commodities produced in the Ohio River basin and Midwest at reasonable cost to coastal ports, in order that they might compete in the international markets, at last brought authorization from Congress for the Davis Island project. International considerations elevated the project from one of purely local benefit for Pittsburgh to a subject of national concern; and an international exchange of waterway technology made possible its construction in the face of intense local opposition.

Farmers and businessmen in the Midwest during the years after the Civil War often blamed the high cost of railroad transport for some of their economic difficulties. They believed excessive railroad rates for transportation from the nation's interior to the coasts placed American commodities at a competitive disadvantage in world markets. They urged that improved waterway transport would provide not only an economical alternative to railroad transport but also force railroads to reduce rates to compete with barge shipments. Midwestern farmers, organized in the Patrons of Husbandry or the Grange, and businessmen at such inland river ports as Pittsburgh, Louisville, and St. Louis,

with a united voice in the National Board of Trade, exercised considerable influence in both state and national politics during the 1870s, and they were behind the many petitions sent from state legislatures to Congress demanding a comprehensive system of waterway improvements. Congress and the national administration were responsive to that widespread public demand: President Ulysses S. Grant in his annual message of 1872 to Congress requested a national waterway study and in early 1873 the U. S. Senate formed a committee to undertake the first comprehensive planning for a national waterway improvement program since early in the 19th century, when Albert Gallatin and John C. Calhoun had completed such studies.[1]

The Senate Select Committee on Transportation-Routes to the Seaboard had Senator William Windom of Minnesota as its chairman, and therefore was commonly known as the Windom Committee. Pennsylvania was not represented on that committee, but the interests of the Upper Ohio valley were well cared for by Senators John Sherman of Ohio, Henry G. Davis of West Virginia, and John H. Mitchell of Oregon, the latter being a native of Western Pennsylvania. Senator Windom initiated an extensive correspondence with the Chief of Engineers concerning waterway projects, asking a number of probing questions about the Ohio: what should be its minimum channel depth, by what means could that depth be achieved, and how much would it cost to achieve it? Relying upon the 1870 report by W. Milnor Roberts because Merrill's studies then had not been completed, the Chief advised the Senator that the channel depth should be six feet, provided through the construction of locks and dams at an estimated cost of about $24 million.[2]

Because the committee also was interested in canals to connect the Ohio River basin by water with the Atlantic coast, it requested and Congress authorized surveys of several canal routes including the Pennsylvania, the Chesapeake and Ohio, the James and Kanawha River, and the Great Western canals. The Pennsylvania Canal, which once had connected Pittsburgh with the Delaware River, had been acquired by railroads and was out of service by 1873. The Chesapeake and Ohio was originally planned to cross the Appalachians and link the Potomac with the Ohio River via the Youghiogheny and Monongahela rivers, but its construction had stopped at Cumberland, Maryland. The James and Kanawha River Canal, like the Chesapeake and Ohio, had originally planned to cross the mountains to the Kanawha, a tributary of the Ohio, but its construction also had stopped east of the mountains. The Great Western Canal, a new project with support in Georgia and Tennessee, had as its goal the connection of the Savannah or other Georgia rivers with the headwaters of the Tennessee River and thereby with the Ohio River. The Windom Committee took interest in those canal routes because Midwestern farmers

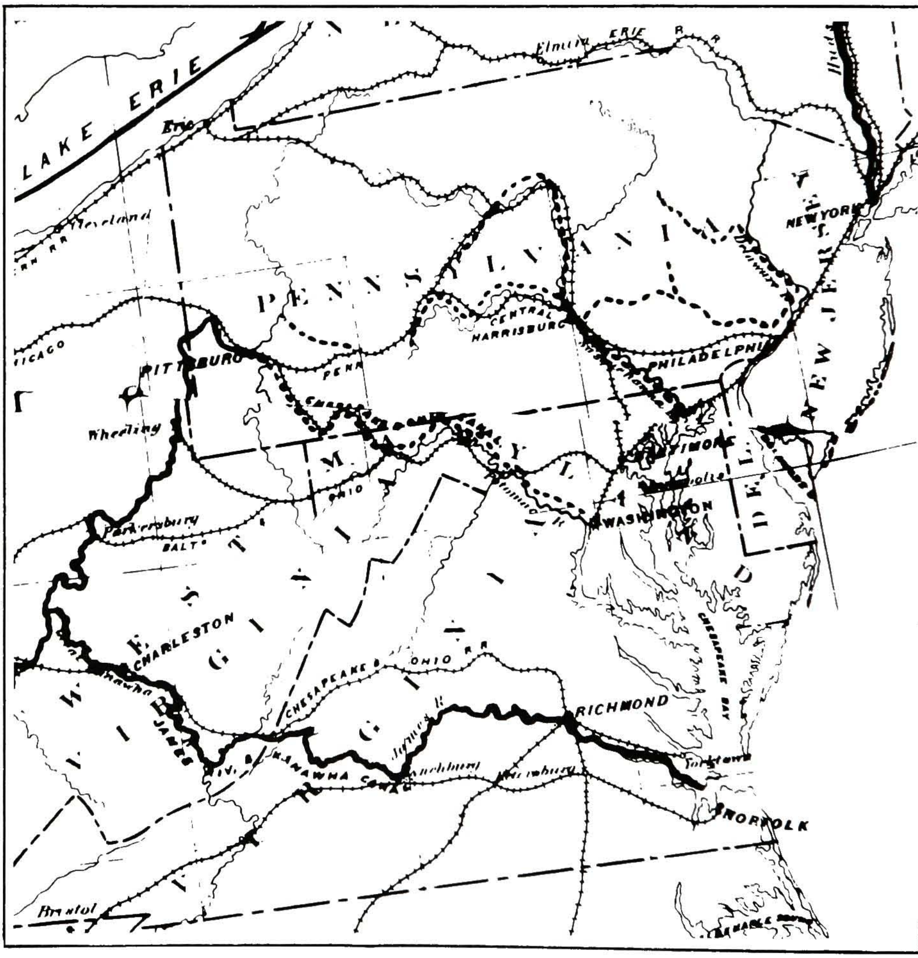
complained the route open to them via the Great Lakes and Erie Canal too often was closed by ice while farm commodities shipped down the Mississippi River suffered heavy losses as a result of heat and humidity. The Committee desired a central route up the Ohio and one of its tributaries and on by canal to the Atlantic, thereby avoiding the cold of the northern and the heat of the southern route.[3]

Assigned the responsibility for surveys of the feasibility of restoring the Pennsylvania Canal to operation and of the possibility of building a canal from the Monongahela River up the Youghiogheny and over the mountains to link with the Chesapeake and Ohio Canal, Merrill in both instances reported the projects feasible but at great costs. Walter McFarland, the Engineer officer at Chattanooga, studied the proposed Great Western Canal from the Tennessee River through Georgia to the Atlantic and also found that route feasible but of very costly construction. The Windom Committee therefore focused its attention on completion of the James and Kanawha River Canal from Richmond over the mountains to Charleston, West Virginia, on the Kanawha. Colonel Merrill at the time was in charge of navigation projects on the Kanawha, but the survey of the "Central Water Line" was assigned to William P. Craighill, the Engineer officer in charge of the James River.[4]

When Craighill returned a favorable survey report on construction of the Central Water Line connecting the James with the Kanawha, the Windom Committee requested the appointment of a special board of review for detailed studies of the proposed canal. The Engineer officers and civil engineer Benjamin H. Latrobe who composed the review board accompanied members of the Windom Committee on a personal inspection of the proposed Central Water Line in 1873, conducting public hearings at cities along the route. Colonel Merrill accompanied that group during its inspection of the Kanawha and Ohio rivers, answering its questions at the public hearings. He told the group that any improvement of navigation on the Kanawha, as part of the Central Water Line, should be similar to those proposed for the Ohio, to which it was tributary, and that both should have a minimum depth of six feet for navigation. He pointed out that no matter which canal route the Committee selected the success of all would be dependent upon the carrying capacity of the Ohio, and the proposed canal would utterly fail "unless the Ohio River is made to give a depth of at least 6 feet through the summer and fall, the time when the canals are doing their heaviest business, but the rivers are at their lowest."[5]

In its 1874 report advocating the comprehensive development of American inland waterways as competition for and as an adjunct to railroad transport, the Windom Committee recommended that Congress fund the construction of four improved waterways designated the Mississippi Route, Northern Route, Central Route, and Southern

Route, all aimed at providing economical transport to the coast for commodities produced in the nation's heartland and thereby allowing those commodities access to world markets at more competitive prices. The Mississippi River channel was to be deepened, especially at the bars obstructing its outlet into the Gulf of Mexico. The Northern Route involved the construction of a canal from a northern tributary of the Mississippi across Illinois to connect with the Great Lakes, and the Southern Route consisted of navigation improvements on the Ohio and Tennessee rivers and construction of a canal from the Tennessee to the rivers of Georgia (Great Western Canal). The Central Route encompassed the improvement of navigation on the Ohio and Kanawha rivers along with the completion of a canal from



A U.S. Senate committee in 1874 proposed establishing a minimum six-foot depth for navigation on the Ohio River and connecting it with the Atlantic through construction of a canal over the Appalachians.

Dr. Leland R. Johnson

the Kanawha to the James River and on to Richmond and the coast. "The improvement of the Ohio River in such manner as to secure from Pittsburgh to Cairo a depth of 6 feet of water at all seasons is," the Windom Committee asserted, "one of the most important works for which the National Government can appropriate money."[6]

By the time the Windom Committee completed its report in 1874, however, national economic conditions had drastically changed. The failure of Jay Cooke's banking house in Philadelphia had launched the "Panic of '73" in the money markets, and a severe economic depression had followed on the heels of the panic. Railroads bankrupted, banks failed, industries closed, unemployment skyrocketed, famine threatened, and the voices of radicals railing against capitalism were heard, even in Pittsburgh. In the opinion of Colonel Merrill, the economic crisis merely provided one more pointed illustration of the need for improved waterways and more economical transport. "Cheap bread is a guarantee against such starving mobs as began the French revolution," he commented while arguing that navigation improvements could reduce the price of grain, "and in these days when the poor are said to be growing poorer, it is a matter that deserves most serious attention."[7]

The Panic of '73 and subsequent economic recession by severely reducing tax revenues ended the chances for a major federal investment in construction of the Central Water Line, and Congress pigeonholed the comprehensive plans for a national waterway network devised by the Windom Committee. Yet, within a few years Congress had adopted on a piecemeal basis many of the Committee's recommendations concerning river projects. It authorized James B. Eads to build his jetties and open an improved outlet for Mississippi River commerce to the Gulf, approved the construction of a canal around the Great Muscle Shoals on the Tennessee River, and funded the construction of locks and dams on the Kanawha and Ohio rivers to establish a year-round six-foot depth for navigation on those streams.[8]

While the Windom Committee's comprehensive waterway study was in progress, Merrill and Weitzel continued their investigation of movable gate systems which might supply what Pittsburgh coal shippers demanded: openings in dams through which coal tows could pass at higher water stages without the delays and costs incident to lockage. By early 1874 they had tested and rejected all the movable gate systems submitted for their consideration except the caisson gate invented by Felix R. Brunot, and their effort to cooperate with General Moorhead in a full scale test of the Brunot gate in Monongahela Dam 1 had failed. Congress did not want public funds expended upon experimental work that might benefit a profit-making corporation, the excuse being that funds appropriated for the improvement of Ohio River navigation

could not be expended on the Monongahela. Having already built the guide walls and chute in Dam 1 needed for the experiment, General Moorhead proceeded on his own, but installed the beartrap gate invented by John DuBois instead of the Brunot gate in the chute. The beartrap malfunctioned, however, the first time its use was attempted and General Moorhead abandoned the experiment.[9]

Colonel Merrill in 1874 expanded his investigation of movable gate systems to the international arena by reviewing European engineering literature furnished him by the library at the Office of the Chief of Engineers. He discovered that European waterway engineering was far in advance of American; in fact, some 124 movable dams had been completed in Europe. German engineers were using the open channel methods, called river regulation, Merrill was using on the Ohio. They had reduced river dredging, spur dike construction, and bank stabilization to a science, but they were having little more success with the methods than he was having on the Ohio. These methods did not provide a reliable depth for navigation during periods of low flow, neither in Germany nor in America. Russians also were using open channel methods on most streams, but had undertaken two interesting experiments on the Upper Volga and Moskva rivers. Russian engineers had built a large dam and reservoir on the Upper Volga to contain flood water for subsequent release to augment stream flow for navigation, a system that had been proposed by American engineer Charles Ellet for the Ohio. A chance existed, in fact, that Ellet might have inspired the Russian experiment, for he had visited Russia during the 1850s seeking to interest the Czar in his engineering services. The Upper Volga reservoir had proven only a partial success, however, and the Russians were building an experimental system of locks and movable dams on the Moskva River. The chief Russian engineer had concluded: "Canalization is the only means, sure and free from errors, to employ for improving the navigability of rivers. All the other methods can be and should be utilized when necessary, but only as auxiliaries, and, moreover, we must be very careful in their application."[10]

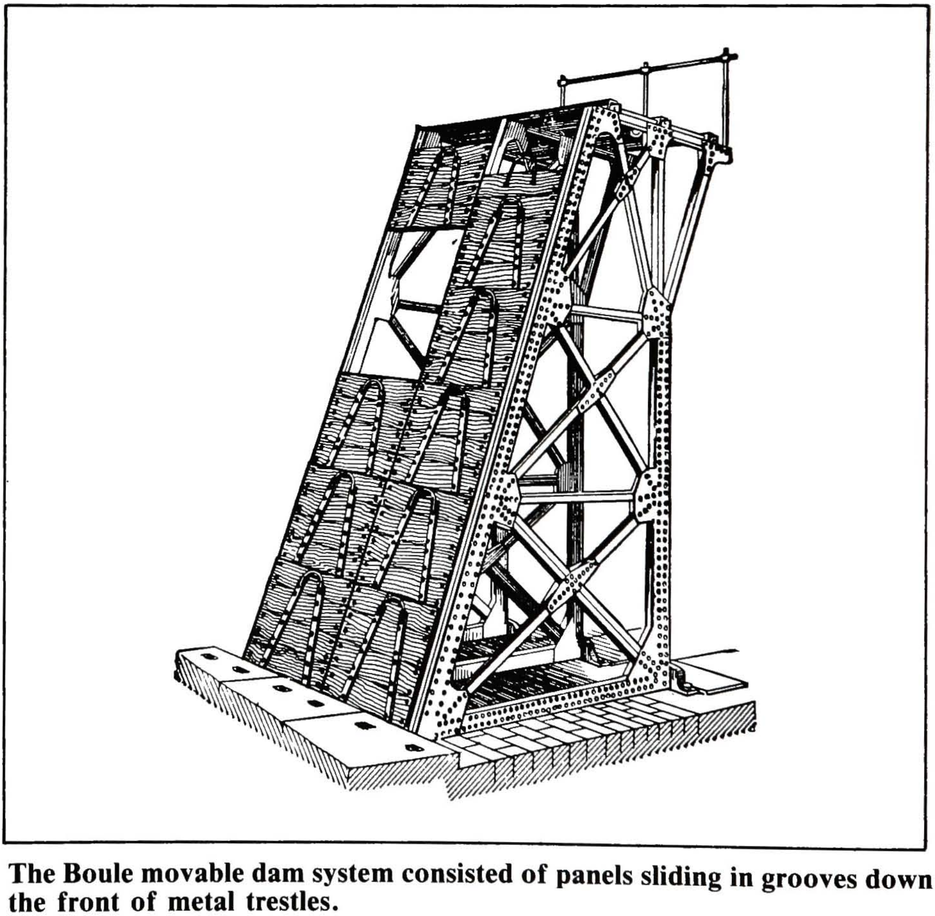
It was in France and Belgium where the greatest advances in waterway engineering technology had occurred. French and Belgian engineers had devised various complex systems of "barrages mobile," or movable dams. As Merrill defined it, a movable dam was "so constructed that it can be used to dam up the waters of a river when it is desirable to do so, and can be taken away when not needed, leaving an unobstructed natural navigation." On the Seine, Yonne, Marne, Meuse, Moselle, and Rhone rivers, Belgians and the engineers of the French Corps des Ponts et Chaussées had built and were experimenting with a wide variety of movable dams. Named after their inventors — Poirée, Desfontaines, Girard, Caméré, Thenard, Boule, and Chanoine,

each of the movable dam systems had distinct advantages and disadvantages. Merrill at Cincinnati and his deputy, Lieutenant Frederick A. Mahan, who also was quite proficient at foreign languages, read everything they could locate concerning European engineering, especially the *Annales des Ponts et Chaussées,* the journal of the French corps of engineers.[11]

Impressed by the superiority of French waterway engineering technology and its practical application to the water resource problems of France during the mid-19th century, Merrill wondered about its origins. He concluded the "germ" of French movable dam technology lay in the the American beartraps built in 1818 on the Lehigh River in Pennsylvania. Josiah White, engineer for the Lehigh Navigation Company, invented the beartrap gates and installed twelve of them in dams along the Lehigh between 1818 and 1820, using them to flush coalboats down the river until 1831 when the Delaware Division of the Pennsylvania Canal was completed. Merrill thought French engineers learned of the Lehigh beartraps during the 1820s and built one at Laneuville-au-Pont on the Marne River, thereby launching the brilliant French experimentation with movable dams. Historical evidence exists indicating that Merrill's views on the origins of movable dams may have been correct; his views may have been parochial, however, for the French built a movable dam in 1778 on the Orb River, using rectangular wooden panels to close the chutes in the dam.[12]

Movable dams actually were an ancient invention. Because navigation locks were not invented until the Renaissance, closing chutes in dams with timbers and removing the timbers to flush boats through dams was a common practice in ancient Egypt and Rome. The same substitute for a navigation lock was often used from colonial times at mill dams on American rivers, and the Union Army once used that device to save a gunboat fleet on the Red River in Louisiana from capture. The French engineers of the 19th century, however, made a series of systematic improvements in movable dam technology. The dam built in 1778 on the Orb River had a series of rectangular wooden panels the size of very large house doors which were hinged at their bottom to the top of the dam foundation and supported in place at their tops by a horizontal timber between stone piers; when the support timber was pulled up, the pool of water upstream of the panels pushed them over on their hinges to fold them down against the foundation. It proved difficult, however, to raise the panels back into place after boats had crossed over the dam, for the head of water rushing over the dam pinned the panels down. Thenard of the French engineer corps in 1832 devised a system of raising the panels with chains attached to a winch moving along a footbridge. British engineers picked up the Thenard system and applied it to dams on the Mahanuddee and Cossye rivers in India and on the Sone Canal.[13]

Starting with the Thenard experiments on the Isle River in 1832, French waterway engineering technology blossomed in a burst of creative engineering seldom matched in world history. Girard modified the Thenard system at Brulée Island Dam on the Yonne by applying a hydraulic piston system which raised the panels like a modern jack raises an automobile. Poirée, chief of the French engineer corps, made an ingenious reversal of the Thenard system in 1834 in a dam he designed on the Yonne River. To raise the panels, the Thenard system required that a footbridge made of metal trestles be raised first for the dam tenders with a winch to move along as they raised the panels; Poirée made the footbridge itself serve as the movable dam by strengthening the trestles and placing wooden timbers called "needles" on the upstream side of the trestles, spacing the needles side by side so closely that they created a dam. Boule of the French corps then replaced the needles with wooden panels exactly filling the spaces between the metal trestles and sliding down to form the dam along grooves on the front side of the trestles. Desfontaines invented a metal



The Boule movable dam system consisted of panels sliding in grooves down the front of metal trestles.

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drum or caisson system of tanks raised and lowered with water pressure and somewhat resembling the system devised by Felix R. Brunot of Pittsburgh.[14]

Colonel Merrill took greatest interest in "les barrages mobiles et automobiles" invented in 1852 by Jacques Henri Maurice Chanoine (1805-1876), chief of the French engineer corps in 1874. Chanoine had directed the construction of thirty-seven locks and dams using his system, mostly on the Upper Seine and Yonne rivers. The Chanoine system especially intrigued Merrill because it was used to facilitate the passage of coal barge tows down the Yonne and Seine to Paris without lockage, exactly the problem Merrill faced on the Ohio.[15]

The Chanoine system was composed of timbers bolted together to form rectangular panels called wickets. When lying flat atop their masonry foundation, the wickets left open a wide space through the dam called the navigable pass, meaning the space in the dam through which navigation passed at higher water stages. When the river receded, dam tenders operating a winch at the dam abutment wound in a chain, dragging up a series of metal trestles from the foundation to an upright position. After the trestles were raised, the dam tenders placed a runway from the top of one trestle to the next, forming a footbridge on which the river could be crossed. Pulling a winch out along the footbridge, the dam tenders grappled with boathooks into the river downstream of the bridge to catch the handles at one end of the wickets, attached a cable from their winch to the handle, and turned the winch to pull the wicket up from the foundation out of the water. Each wicket was hinged to its foundation by a metal framework called a horse and had attached to its back side a metal prop. When the dam tenders lowered the forward end of the timber wicket, its prop caught in a niche in the foundation, thereby propping the wicket in an upright position. Moving from one side of the river to the other, the dam tenders raised and propped each wicket in place until every wicket in the dam was standing, looking somewhat like a board fence across the river and holding a pool upstream of the dam except where water leaked through the gaps between the wickets.[16]

The slackwater pool formed upstream of the wicket covered rocks and bars and allowed normal navigation to continue during periods of low flow, while boats passed through the lock at the end of the dam from one pool to the next. Chanoine dams had long wickets in the navigable pass and shorter wickets in the weir, or overflow, sections next to the pass. While the dam was up, the dam tenders sought to hold the pool at a relatively constant elevation by lowering wickets to pass river rises and raising them after the rises dissipated. When a flood arrived, it was time to lower the wickets to permit the flood and boats riding its crest to cross over the dam without using the lock.[17]

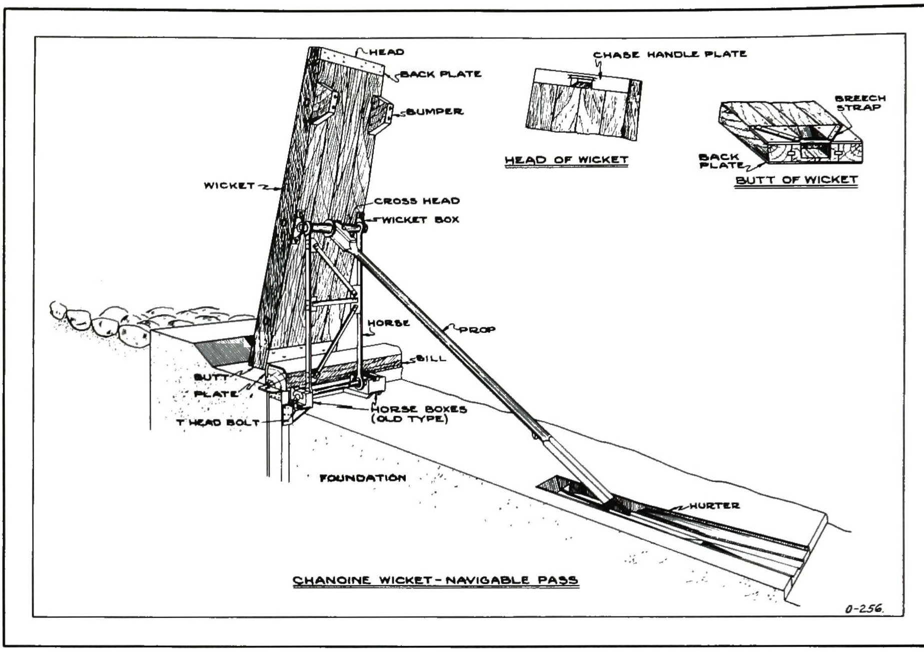

Diagram of the parts of a Chanoine wicket showing the metal prop lodged in the hurter, the horse which hinged the wicket to the foundation, and the four timbers which formed the wicket.

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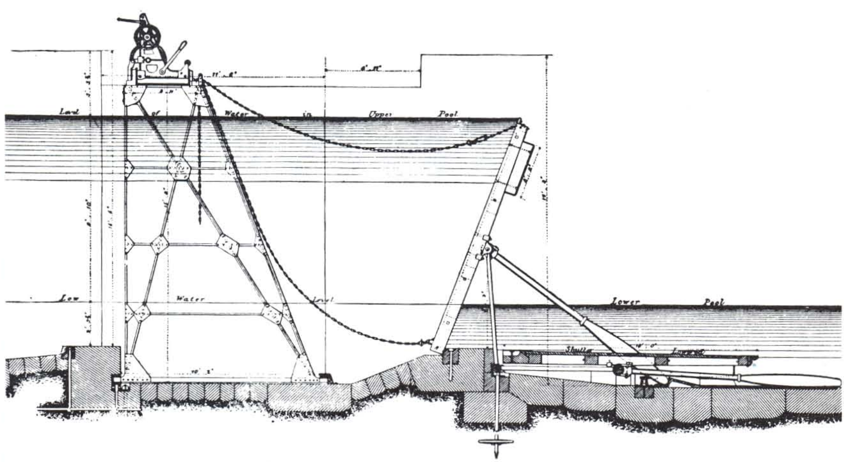
Wickets of the Chanoine system were lowered with a long metal rod called a tripping bar placed in the dam foundation under the wicket props. Along the rod were projections or cams which, when the rod was moved back and forth, struck the ends of the props, knocking them free from their niches and allowing them to slide downstream with the wooden wickets following the props down to collapse atop the dam foundation. With the wickets down, the dam tenders removed the walkway and lowered the metal trestles of the footbridge, called the service bridge. A major advantage of the Chanoine system over the other French systems was the speed in which the wickets of the navigable pass could be lowered. After the wickets of the pass were in place, the service bridge could be lowered out of the way, and when a flood came the pass wickets could be quickly dropped by moving the tripping bar beneath their props; hence, coal tows could pass the lock without waiting for the lowering of each wicket in turn and the removal of the bridge. The job of the dam tenders was more hazardous and considerably more complex than this brief description indicates, but the system served coal barge traffic on the Seine satisfactorily and Merrill found no system better suited for conditions on the Ohio.[18]

Because the system was quite difficult to explain with words,

Colonel Merrill made two models of the wickets in the Port-à-l'Anglais Dam then under construction on the Seine in the center of Paris, one for his own use and another for the use of the Chief of Engineers when trying to explain the system to committees of Congress. Lieutenant Mahan became so enthused about the Chanoine system and French technology in general that he took personal leave and at his own expense went to Paris to see the Port-à-l'Anglais Dam. French engineers, notably Henri Melchoir de Lagrene, gave Mahan a grand welcome, taking him aboard a maneuver boat to observe the raising and lowering of the wickets. De Lagrene, after discussions with Mahan concerning the Ohio River navigation problems, advised him that because of the great length of dam necessary to cross the Ohio it might be well to build the first dam immediately below Pittsburgh and wait several years before building another, allowing time to implement design improvements based upon experience.[19]



Section of the navigable pass of the Port-à-L'Anglais Dam on the Seine River near Paris shows the service bridge upstream of the wicket. The tripping bar was located in the foundation under the end of the prop.

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Mahan returned with bundles of European technical publications including de Lagrene's monumental history of French movable dam design. He and Merrill translated several of the publications into English, and the Chief of Engineers printed and distributed them throughout the Corps. Merrill also offered to translate the multivolume de Lagrene study, but the Chief declined his offer because of high printing costs.[20]

Mahan was so impressed by the Port-à-l'Anglais Dam on the Seine

Lieutenant Frederick A. Mahan was assigned to Pittsburgh in 1872 and became the resident engineer at the Davis Island project.

U.S. Military Academy Archives

that Merrill determined to model the first dam on the Ohio after it. Merrill accordingly in his annual report for 1874 became the first engineer to propose the construction of a movable dam on an American river, proposing to use the Chanoine system, and he and Godfrey Weitzel repeated that recommendation in November 1874 in their final report as the Board constituted to investigate movable dams.[21]

Once the type dam was selected, the next question to settle was the dimensions of the navigable pass and the lock. Because coal barge tows on the Ohio sometimes were six barges, or about 150 feet wide, Merrill decided the width of the navigable pass section of the dam could be no less than 250 feet wide and wider if possible. Locks on the Seine were 40 feet wide and 615 feet long, but Seine River coal tows were smaller than those on the Ohio. The average Ohio River coal tow contained ten barges, each 130 feet long and 25 feet wide, plus a 230 by 48-foot towboat and a 100 by 22-foot flatboat carrying fuel for the towboat. A lock chamber fifty feet wide would be too narrow for steamboat passenger packets, and Merrill therefore selected a 78-foot width, allowing the passage of three coal barges abreast. He

made the length of the chamber 630 feet, which would permit use of the lock by tows three barges wide and three barges long, with the 230-foot long towboat and a fuel flat at the rear of the tow. A nine-barge tow and towboat would be about 75 feet wide and 620 feet long in total, and 78 by 630-foot lock dimensions would provide a clearance of a few feet on all sides of the tow.[22]

Using bills for lock and dam construction costs on the Seine brought back from Paris by Lieutenant Mahan, Merrill estimated that a cutstone masonry lock of the dimensions selected would cost $200,000 and that the cost of the movable Chanoine dam would be $344 per running foot of navigable pass and $227 per foot of overflow weir. To secure a six-foot depth for navigation from Pittsburgh to Wheeling, Merrill reported it would be necessary to build thirteen locks and dams at an aggregate construction cost of $7,474,623. He suggested that if Congress funded construction of all thirteen simultaneously, all the locks could be completed in two years, during which time he could refine plans for the dams and be ready to start their construction during the third year. All could be in operation by about 1880, if only funds were made available. As it turned out, his planning was overly optimistic.[23]

National and international planning in 1874 had elevated the Davis Island and Ohio River project from a primarily local concern for the improvement of the harbor of Pittsburgh to one of national and international significance. Because of agricultural and business desire for better outlets to world markets and the comprehensive study of national waterway improvement projects by the Windom Committee, the Davis Island and Ohio River project was viewed not merely as an improvement of the local and regional transportation but also as a step toward development of a national waterway network capable of moving the produce of the Midwest to the seacoast cheaply, giving American products a competitive edge in international markets. And it was through the studies of Merrill, Weitzel, and Mahan of waterway engineering technology throughout the world that a project design was developed which stood a chance of success in meeting the needs of Ohio River commerce.

IV

PROJECT POLITICAL CONFLICT

The trial of this dam will decide, in the only satisfactory way, the many objections that have been urged against its applicability to rivers like the Ohio; and if no other should be constructed, it will be useful in affording a commodious harbor at Pittsburgh during the low stages of the river, while presenting no serious obstacle to the navigation of the river in its high stages when the wickets will be down.

Horatio G. Wright, 1877

The ironmasters and coal barons of Pittsburgh often shared the same interests, working together for the industrial development of the city, but a serious division occurred concerning the wisdom of building a lock and dam at Davis Island as the first of a series of similar structures designed to canalize the Ohio River. The conflict between iron and coal began in 1871 when a lock and dam to create a harbor for Pittsburgh became the subject of opposing petitions to Congress from Pittsburgh's industrial giants, and it continued nearly a decade both in Congress and in the Pennsylvania legislature at Harrisburg, delaying the start of construction at Davis Island until 1878. That conflict had considerable influence on the engineering design for the Davis Island project, and thereby on the entire Ohio River canalization project from Pittsburgh to Cairo.

General James K. Moorhead, president of the Ohio River Commission, the Pittsburgh Chamber of Commerce, and the Monongahela Navigation Company, and James Negley, Moorhead's successor as congressman from Pittsburgh, badgered the Chief of Engineers and Colonel Merrill throughout 1874 for a speedy conclusion to the movable dam studies and for a favorable report on building a lock and dam to form Pittsburgh's harbor. Shortly after Merrill's recom-

mendations reached Washington, General Moorhead organized a lobbying effort on behalf of immediate authorization and funding of a lock and dam at Davis Island. Moorhead and a large delegation from the Pittsburgh Chamber of Commerce went to Washington in early 1875 to personally buttonhole members of Congress on behalf of the Ohio River project and to offer supporting testimony before congressional committees. They were told they were on a "fool's errand," because the nation was in the depths of the economic depression which followed the Panic of '73 and funding to initiate new civil works projects seemed out of the question.[1]

Though Colonel Merrill had recommended that Congress appropriate $3 million to begin the construction of all thirteen locks and dams on the Ohio between Pittsburgh and Wheeling, the delegation from the Pittsburgh Chamber of Commerce soon recognized that funding on that scale would not be forthcoming. They therefore concentrated upon securing sufficient funds to commence construction of the lock and dam nearest Pittsburgh. As originally drawn, the Rivers and Harbors bill of 1875 included the normal appropriation to continue the open channel work on the Ohio, but not a cent for the Davis Island Lock and Dam and canalization project. The Pittsburgh delegation then went before the House Committee on Commerce, which was considering the Rivers and Harbors bill, to make a last ditch effort to obtain funding for the lock and dam in an amendment to the bill. John H. Ricketson, a member of the Chamber of Commerce's task force, had vivid memories of how General Moorhead dealt with the committee, and he later recalled:

> Finally, General Moorhead arose, and I can see him now as he stood there, still in the vigor of his powers, and in all the magnificence of his presence. Said he: "Gentlemen, I am now only an old horse turned out to grass, but for ten years I represented my district on the floor of yonder hall, and I sat perhaps in the seat now occupied by one of you. In my time an emergency arose every now and then like the one that brings me before you today, and to meet it, we had to go out of the usual order of things. We want $100,000 for the Davis Island Dam, and we want it at once. If we don't get it, not only Pittsburgh interests, but those of the Government will suffer. Now, I want you to do for me just as I would do for you were our situations reversed. I want you to make a unanimous recommendation in favor of this appropriation, and we will pass it by a joint resolution of the Senate and House. Where there is a will there is a way."[2]

As General Moorhead requested, the House Committee on Commerce voted unanimously to allot $100,000 of the $300,000 appropriation for the Ohio River to initiate the construction of the Davis Island project. On the third of March 1875, Congress enacted the Rivers and

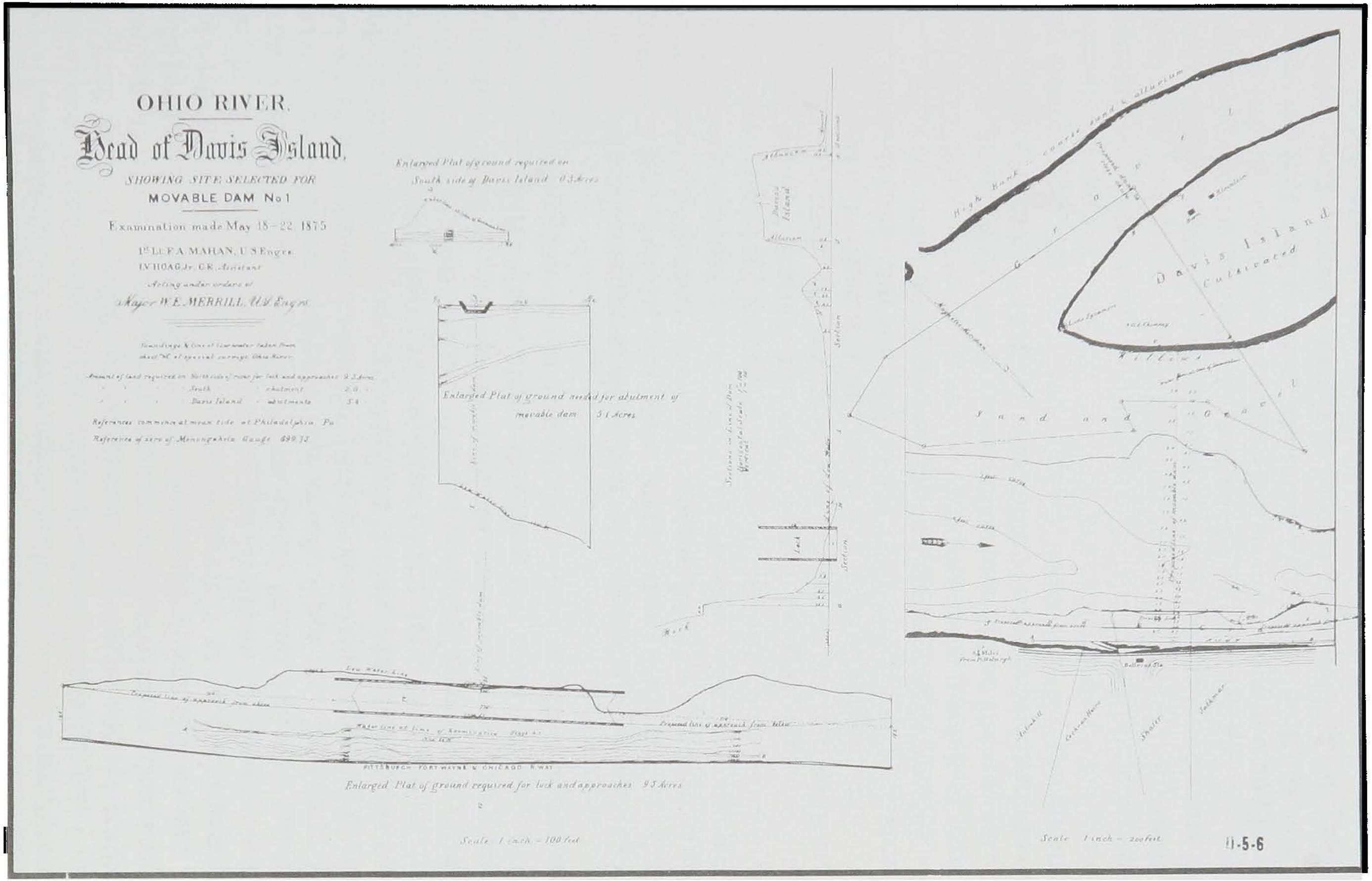
Harbors bill as reported from the committee, providing $100,000 to commence construction of a lock and dam which would provide Pittsburgh with a harbor and launch the canalization of the Ohio.[3]

Recognizing that many complex problems would arise during the final design and early construction phases at Davis Island, Colonel Merrill asked the Chief of Engineers whether he should employ a civilian as permanent resident engineer at the project or place Lieutenant Frederick A. Mahan in charge. Though Engineer officers then were not transferred from job to job so frequently as became the custom in the 20th century, Merrill feared the lieutenant's station would be changed before the construction at Davis Island was well underway and the most challenging problems solved. When the Chief agreed that Mahan could remain on the job, Merrill placed the lieutenant in charge of the project. It proved an excellent choice: Mahan was the son of Professor Dennis Hart Mahan, head of the department of engineering at West Point and author of a standard engineering text, and had grown up in the profession. By 1875, Mahan had already served three years under Merrill's tutelage, directing the construction of dams closing the backchannel at Brunot Island and at other points along the Ohio.[4]

At Merrill's request, the Chief of Engineers in April 1875 appointed a board of officers for a final review of the project design. Composed of Godfrey Weitzel, Orlando M. Poe, and Horatio G. Wright who were among the most experienced waterway engineers in the Corps, the board met at Pittsburgh to examine plans and models, conduct a public hearing, and visit the dam site. Boarding a coal-barge tow, they observed the towing system in use on the Ohio while traveling to Merrill's office at Cincinnati. They granted their approval to the Davis Island dam site and to Merrill's plans and estimates.[5]

Merrill's preliminary project cost estimate of 1874 was $421,425, but in 1875 he had to revise the figure upwards as a result of explorations at the dam site by Lieutenant Mahan. The 1874 estimate was based upon finding a rock foundation for both the lock and the dam. By hammering steel rods with sledges down into the river bottom, Mahan determined that the bedrock beneath the dam was too deep beneath the overburden and the dam would have to be constructed atop sand and gravel rather than bedrock; that condition would increase construction costs. Mahan also contacted the landowners while exploring the foundation and learned they would ask $37,500 for the small strips of land needed on both banks of the river and on the island where the lock and the dam abutments would be built. Merrill had expected land acquisition costs to be negligible and had not included them in his cost estimate.[6]

Merrill revised his construction cost estimate upwards in 1875. Because the cost of buying the land needed was indeterminate, he still



1875 map of the head of Davis Island.

Pittsburgh District, No. 0-5-6

did not include the cost in his estimate, but he privately advised the Chief of Engineers that he thought the land could be had for about $5,000, not the $37,500 asking price. The details of his new cost estimate were:[7]

Lock on rock foundation	$179,610
Navigation pass (400 ft. @ $226.91 per ft.)	90,764
Low weir (500 ft. @ $212.18 per ft.)	106,040
High weir (680 ft. @ $122.44 per ft.)	76,500
Piers	5,351
Abutment	10,375
Backchannel dam (420 ft. @ $78.21 per ft.)	32,848
Lock house	4,000
TOTAL	$505,488

Based upon incompleted designs, those estimates require some explanation. The lock house would be constructed on the north or right bank of the river next to the stonemasonry lock, built atop a rock foundation. Adjoining the lock would be a pass for navigation at least 400 feet wide closed by Chanoine wickets, with a masonry pier dividing the pass from the weirs. The fixed foundation of the weirs would be higher than the foundation of the pass because boats would not pass over the weirs; the pass foundation would be flush with the river bottom, the low weir foundation would be a foot above the river bottom, and the high weir foundation would be two feet above the river bottom. The wickets in the weirs therefore would be one and two feet shorter than those used in the pass. (Merrill later increased the number of weirs to three, with their foundation elevation being one, two, and three feet above the river bottom.) Masonry piers also would divide the weir sections and a masonry abutment would tie the dam into the head of Davis Island. A stone-filled timbercrib dam would block the backchannel between the island and the south or left bank of the river.[8]

It therefore was necessary to purchase a strip of land along the north bank of the river for the lock and lock house, to buy the upper end of Davis Island, and to acquire a short strip of land on the river's south bank against which the backchannel dam would abut. Captain Thomas Mulvehill, William Jackman, and Noah W. Shafer owned the three parcels of land on the north bank needed for the lock and lock house. Captain Mulvehill, one of the coal shippers who opposed the project, used his river front property for barge moorage and he demanded a very high price for the land. Jackman and Shafer told Mahan they wanted to do whatever was "fair and right," but the price of fairness came high. David Davis owned the upper end of the island and pointedly refused to sell an inch of his property. Mrs. James Graham, the daughter of Thomas McKee, owned the land on the south bank where the backchannel dam would abut, and she and her hus-

band also refused to negotiate a price, stating they wished the value of their land determined by independent appraisal.[9]

Lieutenant Mahan returned to the dam site several times, seeking to negotiate a fair price with the landowners, but the owners increased rather than decreased their asking prices. "It seems to me," Colonel Merrill told the Chief of Engineers, "that the landowners are disposed to make the government pay more than the land is worth and that the only protection will be to secure from the State a power to appraise and condemn." In view of the "exorbitant" sums asked by the landowners, the Chief of Engineers in June 1875 directed that project construction be held up until the Pennsylvania legislature enacted a law granting to the United States jurisdiction over the site of the lock and dam and the authority to condemn the needed lands in the courts under the power of eminent domain.[10]

General Moorhead and Colonel Merrill drew up a bill by which Pennsylvania would cede jurisdiction over the Davis Island project to the United States, and General Moorhead had it placed on the calendar of the state legislature. Both houses of the legislature enacted the bill at their first consideration, but Governor J. F. Hartranft vetoed it on grounds that the title of the bill did not fully disclose its contents. General Moorhead revised the wording of the bill to meet the Governor's objections and had it reintroduced to the legislature, where it passed the House but in the Senate was mysteriously mislaid and could not be found for action when called up in its order. The bill came again before the legislature in late 1875 as unfinished business, but on that occasion it was soundly defeated because of the intense opposition to it offered by Pittsburgh coal interests.[11]

Rather than abating, the opposition to the project had grown louder after Congress funded it. At meetings in 1875 of the Pittsburgh Coal Exchange and the Pittsburgh Steamboatmen's Association, a joint committee was established to present their opposition to the public and before Congress. In a memorial addressed to Congress, the committee asserted that barges carried Pittsburgh coal a distance of 2,000 miles to New Orleans for eighty cents a ton, or less than a half mill per ton mile, a cost that was one-twentieth of the comparable railroad rate and which constituted the cheapest transportation service in the world. They feared Merrill's plan for Davis Island and the Ohio River would "utterly ruin and annihilate" barge-towing on the Ohio.[12]

The Corps of Engineers then collected tolls from barge traffic using the Louisville and Portland Canal on the Ohio (and continued to collect them until 1881), and rivermen thought those tolls exorbitant. They warned that similar tolls collected at each lock built along the Ohio would destroy their business. They feared the complex Chanoine wicket system proposed for the Ohio would be constantly out of service for repairs, that the empty tows returning upstream would

be unable to breast powerful currents through the navigable passes of the dams, and that the Davis Island pool would gorge with Allegheny River ice and destroy any craft afloat in the pool. In the summers, they warned, the Davis Island Dam would create a foul, stagnant pool, poisoned by municipal effluents and noxious discharges from the oil refineries, "diffusing sickly and fatal influences, and generating pestilent insects and noisome odors."[13]

Rivermen and coal barons urged Congress to kill the "tampering experiment" at Davis Island and to continue the open-channel clearance project previously authorized for the Ohio. Because the Ohio River drained an area as large as all of France, they contended the Chanoine system would not function on the Ohio as it had on the Seine and the smaller French rivers. If experiments with the Chanoine systems were deemed imperative, they wanted those experiments restricted to the smaller Kanawha River in West Virginia.[14]

In a published critique of the coal shippers' objections to the Davis Island and Ohio River project, Felix R. Brunot declared the objections were merely echoes of the objections heard many years before in Pittsburgh when he, W. Milnor Roberts, and James K. Moorhead had proposed the construction of locks and dams on the Monongahela River. Brunot contended the successful operation of the Monongahela project during thirty years had effectively refuted exactly the objections presented against locks and dams on the Ohio. "We could hardly expect the owners of an $80,000 towboat," said Brunot, impugning the coal shippers' motives, "to be pleased at first blush with an improvement which will enable a $4,000 or $5,000 tug with its barges by running safely all the year round, carrying coal down and freight up, to be a successful competitor."[15]

"Unjustifiable and contrary to public policy" was Merrill's opinion of the position of the rivermen and coal shippers. He asserted that they condemned in advance the construction of even a single lock and dam on the Ohio as an experiment in spite of the prediction that it would provide great benefits to Pittsburgh interests including the coal shippers themselves and notwithstanding the fact that if the experiment proved a failure the dam could easily be blasted out of the channel to restore open river navigation. He believed the steamboat packet business along the Ohio to have a value far in excess of the value of the coal shipments, and he sent his chief clerk, Henry Smith, to Pittsburgh to collect comparative statistics.[16]

The clerk reported that in 1876 the steamboat freight and passenger packet trade at Pittsburgh included 60 boats departing the wharf bound for Wheeling, 26 for Marietta, 40 for Ironton, 38 for Portsmouth, 62 for Cincinnati, and 42 to Louisville and below, or a total of 268 packets leaving Pittsburgh during the year. Coal barge tows departing Pittsburgh during the same year included 9 bound for

Wheeling, 1 for Parkersburg, 20 for Ironton, 151 for Cincinnati, and 176 to Louisville and below, or a total of 357. In addition, there were 24 petroleum barge tows which left for Huntington, West Virginia, and 25 tows of assorted freight bound for Mississippi River ports, bringing the total number of packet and barge tow departures from Pittsburgh in 1876 to 684. Merrill estimated the value of the cargoes transported aboard the packets at $200 million and the value of those aboard the barge tows at $6 million. Coal shippers, therefore, should not be allowed to dictate the character of the project adopted for the improvement of navigation along the entire course of the river.[17]

Merrill pointed out that French engineers had been plagued by many theoretical objections to the Chanoine system from Seine River coal shippers, that the extraordinary conditions predicted by coal shippers there had not developed, and that Seine River coal shippers had eventually become the strongest advocates of extending the project along the river to Paris. He told the Ohio River coalmen that no tolls would be collected for using the navigable pass at the dams, that tolls for use of the locks would be light, and that the capability for year-round operation would more than adequately compensate for the expense of tolls. Because the coal fleet no longer would run only at high water and tie up the remainder of the year, smaller dealers could profitably enter the trade, coal gluts or famines at downriver ports would be eliminated, and the price of coal delivered to consumers could be reduced. The construction of the Davis Island Lock and Dam should proceed, he concluded, because benefits to consumers would be incalculable.[18]

Coal shippers were distinctly unimpressed by Merrill's replies to their objections. They continued to fight granting jurisdiction at Davis Island in the state legislature and to oppose additional project funding by Congress, and they sometimes visited the Chief of Engineers to make their protests in person. "I think Col. Merrill or any other Engineer should hesitate a good while before adopting so imperfect a machine as the Chanoine system," one coal baron told the Chief, and "thereby obstructing so great and important a highway as the Ohio River."[19]

The Chief of Engineers in early 1877 convened a special Board of Engineers to consider the protests against the project, appointing Merrill, Weitzel, Horatio G. Wright, and Zealous B. Tower to the Board. After study of the opposition's arguments, the Board reported that the value of coal towed on the Ohio was no more than 5 percent of the total value of commodities moving on the waterway and the interests of commerce other than coal necessarily deserved full voice in planning the Ohio River project. It predicted that congestion at locks of the sort experienced on the Monongahela would not occur on the Ohio because the new locks on the Ohio would be capable of han-

dling ten rather than merely two barges in a single lockage and the navigable passes would permit the passage of coal tows without any lockage whatsoever. Canalizing the Ohio, moreover, would alleviate the economic troubles at ports downstream of Pittsburgh where industries sometimes had to close for lack of fuel during low river stages. The Chief of Engineers concurred with the findings of the Board and determined the construction of the Davis Island Lock and Dam would proceed as soon as Pennsylvania enacted the bill granting jurisdiction over the land to the United States.[20]

After the jurisdictional bill had failed of passage three times in the state legislature, General Moorhead and the Pittsburgh Chamber of Commerce pulled every available political string during the 1876-1877 session. A delegation of ironmasters and attorneys, headed by Henry W. Oliver, went personally to Harrisburg to see to the enactment of the bill. Oliver had organized an iron and steel company in Pittsburgh in 1863 to produce nuts and bolts; he later expanded it to include iron furnaces, mills, and a fleet of ore ships on the Great Lakes. Oliver Street in downtown Pittsburgh bears his name, and his company formed the nucleus of the United States Steel Corporation; he lived two doors from General Moorhead on Centre Avenue in Pittsburgh. Oliver lobbied hard for the bill at Harrisburg in 1876, but his efforts seemed a failure. Expecting defeat at Harrisburg, General Moorhead blamed it on "corruption." Thus warned, Colonel Merrill requested authority to go to Harrisburg and appear before the legislature on behalf of the bill; his request was denied, but the Chief of Engineers did arrange for the Secretary of War to make a personal appeal to the Governor. After the newspapers in February 1877 had reported the defeat of the bill, Henry Oliver "snatched victory from defeat" by accepting amendment in committee to secure additional support for the bill, and it was at last enacted and signed by the Governor in March 1877.[21]

During the lengthy delay awaiting enactment of the bill, Merrill and Moorhead visited with the landowners at Davis Island to negotiate prices, and thanks to those personal appeals the owners of the land where the lock was to be built reduced their prices. Doubting that condemnation proceedings would further reduce those prices, Merrill settled with those owners. Davis and the Grahams, owning the island and the land on the south bank, refused to negotiate a price, however, and it became necessary to condemn those properties in court. The United States District Attorney at Pittsburgh handled the condemnation litigation, which dragged on for more than a year. "The public mind at Pittsburgh," Merrill wearily advised the Chief of Engineers, "is becoming much disturbed at the apparent inaction of the U.S. Authorities." Not until June 1878 were all the lands needed for the project acquired and the titles properly registered. By refusing to

pay the landowners the $37,500 they asked in 1875, Merrill saved the government $22,500, for the land was at last acquired for about $15,000. But the delay had provided coal shippers with time to raise in the public mind serious questions about the wisdom of the project plans.[22]

Colonel Merrill had retreated during the delay from recommending the simultaneous construction of all thirteen locks and dams between Pittsburgh and Wheeling to advocacy of the construction of a single lock and dam as an experiment, with no further structures to be built until the first had proven its effectiveness. That delay and project retrenchment eventually was to prove destructive to Ohio River commercial navigation in general and to Pittsburgh coal shippers in particular.

With undivided support from West Virginia coal shippers, Colonel William P. Craighill on the Kanawha River managed to begin construction of a system of locks and Chanoine dams in 1875, three years before Merrill could begin on the Ohio. Kanawha coal shippers wished to compete with Pittsburgh coal in the Ohio and Mississippi River coal trade, and they needed locks and dams on the Kanawha to accomplish that. Craighill and his assistant Addison M. Scott finished the first lock and movable dam on the Kanawha in 1880 and completed the last of ten dams on the river in 1898, affording Kanawha coal easy access to the Cincinnati and downriver markets and developing a formidable competition for the coal barged from Pittsburgh. Not even the second lock and dam had been finished on the Ohio by 1898.

V

LOCK CONSTRUCTION COMMENCES

One of the most serious objections argued by coal men against the proposed Ohio River locks is their narrowness — 78 feet. The normal width of a coal fleet is 100 feet, and if it is possible to make the lock 103 feet wide it will at all times admit the normal fleet without making it necessary to break up and reform the tow, operations that my own experience has shown to be tedious as well as hazardous.

William E. Merrill, 1877

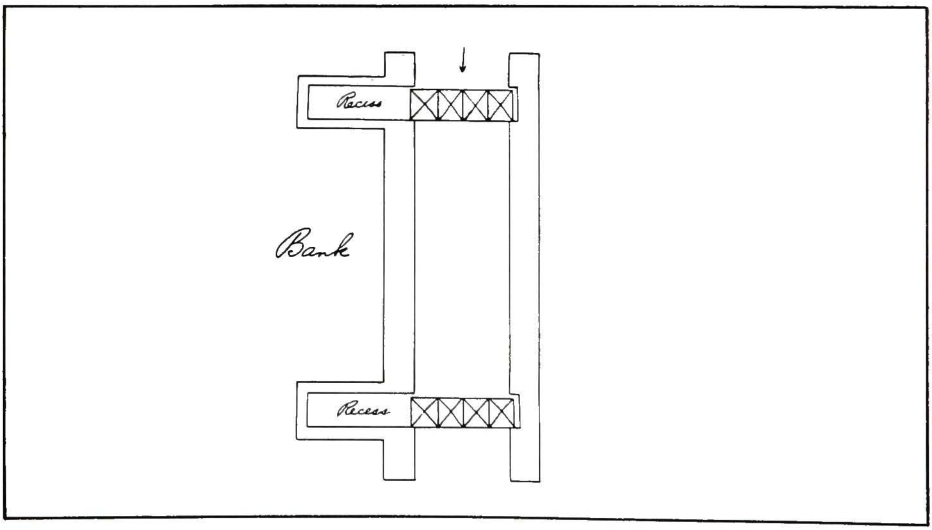
Colonel Merrill used the time consumed by the land acquisition litigation to inspect waterway projects in Europe and to redesign and improve the Davis Island project. Coal shippers had complained about his 1875 plans calling for a lock that was 78 feet wide and 630 feet long capable of handling in a single lockage a towboat, fuel flat, and nine barges, objecting that the normal coal tow leaving Pittsburgh was 100 feet wide and had ten barges. Even if they reduced the number of barges in a tow to nine, they still would be forced at each lock to disconnect the towboat from the center at the rear of the tow and move it to the side in order to have room inside the lock for a fuel flat alongside the towboat. Merrill knew that was true, but what could he do? The seventy-eight-foot lock chamber width matched the largest locks ever constructed.[1]

The normal coal tow had four barges abreast, each about twenty-five feet wide, for a total width of one hundred feet, and a lock capable of handling such a tow would necessarily be more than a hundred feet wide to provide clearance at the sides of the tow. The lock gates then in use on inland rivers were fabricated of wooden timbers and were the mitering type, having two leaves attached at the heel ends to the lock walls and swinging like common house doors to toe together in

the center of the lock chamber. To close a lock more than a hundred feet wide, each leaf of a mitering lock gate would have to be about sixty feet long. At the Davis Island Lock, the gates were to be only fourteen feet high, and if sixty feet long, the height to width ratio would be four to one. The stresses generated by sixty feet of lock gate hanging suspended from a lock wall would tear the lock gate loose from its anchorages, and it would inevitably sag at the middle of the lock chamber. Such lock gates could not, with the materials and technology available in 1877, be built.[2]

Merrill during the 1860s had become an authority on railroad engineering and bridge truss design, and his consideration of the lock gate problem naturally turned into that channel. If bridge spans greater than a hundred feet in length could support locomotives and trains, why not build a lock gate like a bridge truss to span a hundred-foot lock chamber and bear the pressures exerted by the upstream pool of water? Selecting a Howe truss of the type commonly used in railroad bridges, he decided it could bear the weight of the upstream pool if it were laid on its side and supported at each end by the masonry lock walls. To open the lock for the entrance of boats, it would be necessary to move the bridge truss to one side into a recess or opening in the land wall of the lock. The truss could be mounted on wheels and roll on a railroad track on the bottom of the lock in and out of its recess, pulled by a chain attached to a steam engine or another power source.[3]

With that concept in mind, he examined engineering literature for precedents and at last found it in *Spon's Dictionary of Engineering,* a multivolume encyclopedia of engineering published in 1874. The



The sketch drawn in 1877 by William E. Merrill to illustrate for the Chief of Engineers his plans for a rolling gate with Howe trusses to close a 110-foot wide lock chamber.

National Archives, Record Group 77

British Navy was using a similar "caisson gate" to close the entrance to its drydocks for ship repair at Cork, Ireland, and Glasgow, Scotland. He quickly penned a letter to the Chief of Engineers describing his lock gate concept and including a sketch for clarification, asking the Chief to contact British engineers for more information about the gates used at the drydocks. Through the Secretary of State and the American ambassador in London, the Chief acquired the information and convened a Board of Engineers to review Merrill's new lock gate system. Merrill in the meantime perfected his design and had a scale model of his rolling lock gate built to demonstrate its operation. In defense of the cost of the model, Merrill told the Chief of Engineers: "A model is almost invaluable in designing a novel structure of any intricacy, as it enables one to discover defects before they have been perpetuated at great cost in the structure itself."[4]

Meeting at Cincinnati in January 1878, the Board of Engineers learned that Merrill's rolling lock gate somewhat resembled a railroad car that was 14 feet high, 13 feet and 8 inches wide, and 117 feet long. When closing a 110-foot wide lock chamber, the gate would lap 3.5 feet onto the lock walls at each end of the chamber. Made of pine timbers, the Howe bridge truss lay on its side at the top of the lock gate, with the vertical timbers of the gate supporting it and extending down to fifteen railroad trucks, or carriages, having thirty standard rail car wheels — the same trucks and wheels then used beneath 50-ton rail cars. They rolled on a rail track with an 11-foot and 8-inch gauge laid on the bottom of the lock chamber and into the gate recess in the lock wall. Housed in the recess in the lock wall when not in use, the lock gate rolled out along the rails across the chamber to close the lock, pulled out into position by a chain winding around a drum.[5]

Merrill explained to the Board that the new lock gate would permit changing the proposed lock dimensions at Davis Island from the 78 by 630 feet approved in 1875 to 110 by 600 feet. The thirty-foot reduction in length was made possible because the rolling lock gates would not need space inside the chamber to swing open and shut as miter gates did, and the shorter lock length also would offset the increased costs incurred for building the new lock gates. The 110-foot width in the chamber would permit the standard ten-barge tow to use the lock without rearrangement; the tows could be four barges abreast, with four in the second row, and two at the rear alongside the towboat.[6]

Recognizing that a larger lock capacity could better serve Ohio River commerce, the Board of Engineers granted its general approval to Merrill's rolling lock gate plans. It suggested that it might be better to make the bridge truss of iron rather than timber and that a steam engine might be the best source of power for pulling the gates in and out of their recesses. The Board was willing, however, to trust Merrill's judgment in those matters as well as other design questions, and it

recommended that he be given "great latitude in all the details as time and experience are constantly suggesting minor changes and modification which the engineer should be at full liberty to adopt without the formality and loss of time required to submit a formal application for authority."[7]

Approving the Board's recommendations, the Chief of Engineers gave Merrill the authority to modify the design details and also issued orders for Merrill to travel to Europe and inspect the construction and operation of the Royal Navy's drydocks and of the Chanoine dams on the Seine. Merrill spent the spring of 1878 touring the public works of Europe, often with distinguished engineers from each nation as his guides. European waterway technology impressed him, especially the use of concrete as a substitute for stonemasonry.[8]

American engineers in the 1870s were using a natural cement as mortar in stonemasonry construction, not as a substitute for masonry. The cement was made of burned limestone through a process introduced by Canvass White on the Erie Canal in 1818, and its quality was quite variable. Merrill learned that European engineers had taken advantage of an improved Portland cement for concrete production on a large scale, and on his return from Europe he decided to use concrete, because of its economy and speed of placement, in all structural features at the Davis Island project which were not subject to heavy pressures and stresses. Because suitable Portland cement was not manufactured in America during the 1870s, he could not secure the improved cement for use at Davis Island, but used instead the natural hydraulic cement manufactured at Louisville, Kentucky, and near the Erie Canal in New York at plants established by Canvass White. Merrill thereby became one of the first American engineers to adopt concrete as a substitute for ashlar masonry, though he restricted its use to foundations and continued to build with stone masonry the lock walls, piers, and other structural features subject to stress and weathering.[9]

In June and July 1878, Merrill prepared his final construction plans for review by the Chief of Engineers. Because the Davis Island project was experimental and because of some earlier unfortunate experience with contractors, he decided to perform the construction with hired labor under government supervision, declaring that "first-class hydraulic work ought never to be done by contract, as unfaithfulness in a single joint may entail most disastrous consequences." Government force account construction would also permit the maintenance of exact cost records for each project phase, providing data that would be useful in planning the construction of additional locks and dams farther downriver.[10]

Of the $100,000 appropriated in 1875 and the $150,000 appropriated in 1878, Merrill had expended $17,000 for surveys, founda-

tion studies, and land acquisition, leaving a balance of $233,000 for the 1878 construction season. He planned to apply that sum in 1878 to construction of the lock's land wall along the north bank including its two gate recesses; the lock wall would be standard stonemasonry and the recesses would be concrete of the sort he had seen used to build the Victoria Docks in England. He also wanted to build the lock house during the first year to serve as a resident engineer's office during construction and subsequently as an office for the lock operations, but he encountered a bureaucratic snag blocking construction of the lock house.[11]

In his original estimate of project costs, Merrill had failed to include the cost of the lock house, "it having been overlooked in the discussion of more important and difficult matters." He wanted to build a plain, square brick lock house, to be "2-stories high with 8 living rooms for two married and two single lock tenders, an office and a store room," and he estimated it would cost about $9,000. But Major John G. Parke, the assistant to the Chief of Engineers in charge of river and harbor projects, told Merrill the lock house could not be built. Because it had not been included in the original project cost estimate approved by Congress, project funds could not be expended on lock house construction until Congress included it in a subsequent appropriation.[12]

Major Parke, whose duties at the Office of the Chief of Engineers were equivalent to those of the modern Director of Civil Works, was a personal friend of Merrill. They had met during the Civil War, when Parke had risen to the rank of major general in command of the Ninth Corps of the Army of the Potomac, and had continuous contact thereafter, for at the close of the war, General Parke had reverted to the rank of major in the Corps and become the assistant to the Chief for rivers and harbors, a post he held for twenty years until 1887. Parke often orchestrated elaborate banquets for prominent Washington politicians, which gossip said had "a very ameliorating effect" on legislation in which the Corps of Engineers was interested. In private correspondence, Merrill addressed the General as "My dear Parke," and through that connection he managed to secure approval for building the lock house.[13]

Merrill in a private letter to Parke explained the lock site was on the side of a steep railroad embankment beneath a vertical cliff a hundred feet high and there were no houses in the vicinity that could be rented as quarters for the staff or as office space. The foundation for the lock house had to be constructed first because it was to be located in the space behind the lock wall that would be backfilled. He pointed out that General Moorhead and other project proponents wanted the lock house built first because it would demonstrate construction progress, and "they think that the greater appearance of the

work done before Congress meets, the greater chance of a liberal appropriation, and the less danger of interference from parties hostile to the work.'' Besides, Lieutenant Mahan needed to be available on the job day and night, and did not wish to risk his life at night, when passenger trains did not run, by walking the four miles to and from Pittsburgh along the railroad track. Through that personal appeal, Merrill at last secured authority to start construction of the lock house during the 1878 season.[14]

Merrill left the hiring of civilian personnel for the project largely to the discretion of Lieutenant Mahan, who employed an impressive staff. As his chief assistant, a job roughly equivalent to that of a project engineer, Mahan hired James H. Harlow, a founder of the Engineers' Society of Western Pennsylvania who had been a municipal water supply engineer and contractor, building water works at Pittsburgh, Boston, and New Castle. William Martin, who had worked with Harlow in building the Pittsburgh water works, became the assistant project engineer. The chief clerk was William R. Lowe who had commanded the 19th U. S. Infantry during the Civil War and who spent the remainder of his life as an office administrator, ending his career in the Office of the Chief of Engineers. J. R. Meredith became the master machinist in charge of derricks, engines, and construction tools, and made several innovative contributions to the project's construction. Robert W. Fulton became the timekeeper, a complex task because separate records were maintained on every class of work for the information of the Corps for the planning of other projects. Those were the project's executive and administrative staff, and they were salaried, earning from $90 to $150 per month.[15]

The workmen at Davis Island Dam pose in 1881 atop the navigable pass wickets inside the cofferdam. Note the steam power house and the lock house in the background.

Carnegie Library of Pittsburgh, No. B-998

The construction workers were supervised by three overseers and nine suboverseers, equivalent to modern construction superintendents and foremen. Two overseers directed work at the two quarries where dimension stone for the lock walls was produced and the third, Terence McSwerney, headed the crew working at the lock. Overseers earned $3 per day, suboverseers $2 a day, and skilled workmen and laborers less; and a day then, before the enactment of eight-hour labor laws, could be as long as fourteen hours. During the peak of the construction season, about three hundred men worked on the job, half at the two quarries and the other half at the lock. Because most workmen commuted to and from the job by train, Merrill made arrangements with the railroad for reduced fares, and the workmen purchased some 66,000 commuter tickets before the construction job ended.[16]

With preliminary planning and hiring completed, Lieutenant Mahan took a contingent of workmen to the lock site on the nineteenth of August 1878 and began clearing brush and trees from the site, initiating the construction of the Davis Island Lock and Dam. He leased stone quarries at Stoops Ferry and Baden, eight and fifteen miles downstream of the lock site, where workers cut cubic-yard blocks of sandstone from the face of the quarries and chiseled them to the precise dimensions required for use in the lock walls. The stone was

Quarrymen cutting the stone to be used in the Davis Island Lock. The derrick at the right is preparing to lift one of the dimension stones.

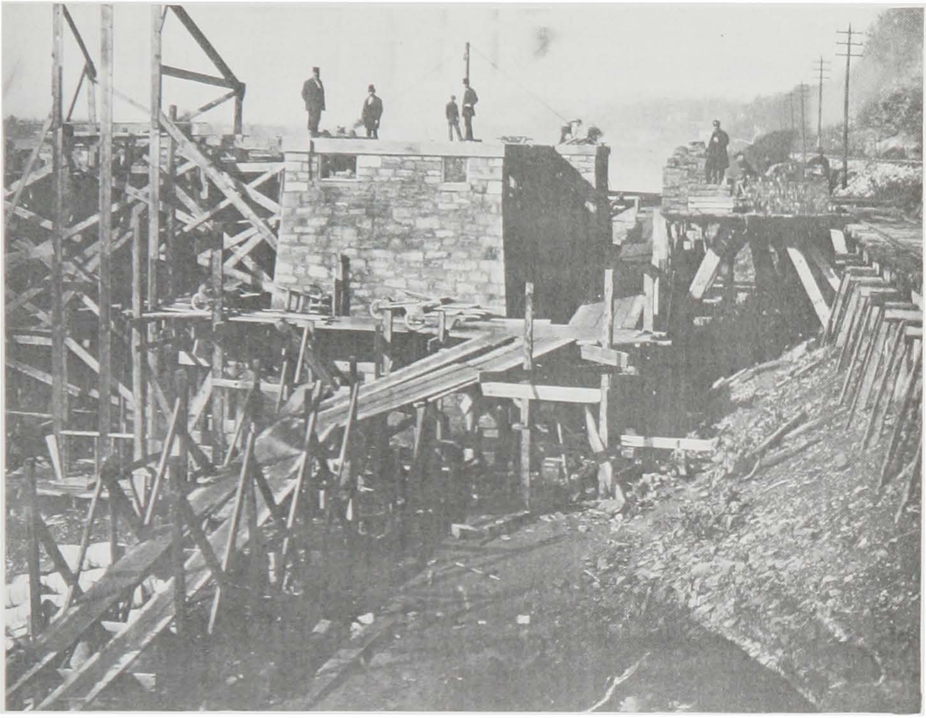
Carnegie Library of Pittsburgh, No. B-1028

shipped upriver to the lock in barges when river stages permitted and by railroad at other times. The Pittsburgh, Fort Wayne, and Chicago Railroad, which paralleled the river along its north bank under the high bluff and passed immediately back of the lock site, earned a substantial sum during project construction, receiving some $40,000 for the transport of stone, cement, and other materials.[17]

After the lock site was cleared of vegetation, excavation of the soil overlying the bedrock on the river bank and construction of a cofferdam began. The lock was to be built inside two cofferdams, one for the land wall and the other for the river wall, both being temporary structures to hold out river water while the site was excavated and the lock walls constructed. The first cofferdam, extending from the bank upstream of the lock out into the river and running some 600 feet downstream before returning to the bank, was completed in September. After water inside that cofferdam was pumped out, excavation began inside to remove the mud and gravel (overburden) from atop the bedrock on which the lock wall masonry would be erected. To store cement, tools, and materials, temporary frame buildings were put together atop pilings driven next to the river bank. The thirty-five-foot high foundation of the lock house also was constructed, for

The lock house foundation was under construction in this 1878 picture with a brick sewer line behind the foundation. In the background is the wall of the cofferdam built around the lock's land wall.

Carnegie Library of Pittsburgh, No. B-1014



The lock house foundation was nearly completed in this picture. Note the wheelbarrows and ramps used to move the construction materials.

Carnegie Library of Pittsburgh, No. B-1031

it was necessary that the foundation be in place before the area behind the lock wall was backfilled. Before flooding and cold weather suspended the work in late 1878, $115,500 had been expended on the preliminary construction jobs.[18]

The opposition to the project did not cease their protests at the start of construction, and in fact redoubled their efforts to persuade Congress to cut off construction funding. Merrill's attempts to satisfy the opponents to the project through the adoption of a Chanoine dam with a navigable pass, through the design of the widest lock ever built, and through limiting the work to a single experimental lock and dam had failed. In early 1879, Pittsburgh rivermen and coal shippers conducted meetings in Pittsburgh to protest, claiming the project would create conditions injurious to public health, that the Chanoine system would never work on the Ohio, and that it would benefit the few "unscrupulous and selfish" ironmasters while injuring the interests of some 15,000 coal miners and boatmen. Some rivermen believed that James K. Moorhead, Henry Oliver, and other ironmasters hoped the dam would close Ohio River navigation, thereby insuring that the Monongahela coal would remain at Pittsburgh to assure their iron mills a continuous supply of cheap fuel. They described the Davis Island

project as one of the "delusions of a theoretical engineer."[19]

It was against policy for Corps officers to respond to their critics in the public media, but Colonel Merrill could not resist replying to a demand printed in a Pittsburgh newspaper that he be replaced by a "practical" riverman. In a letter to the editor, he commented:

> Permit me to say with all due respect to a very worthy class of men, with whom I'm glad to state that my relations have always been exceedingly kindly, that the improvement of rivers is the work and study of engineers the world over, and the fact that a man habitually travels on a river no more qualifies him for correcting channels, protecting banks, preventing overflows, building locks and dams, and doing the various other work of a hydraulic engineer than the continual travel of a railroad conductor fits him for building the bridges and tunnels of a railroad.[20]

The aim of the project opponents was to stop Congress from appropriating more funds for construction in 1879, and to thwart that effort the ironmasters of Pittsburgh, including Moorhead, Oliver, and Andrew Carnegie among others, conducted mass public meetings of their own in support of the project. They controlled the Pittsburgh Chamber of Commerce, and when John F. Dravo of the Pittsburgh Coal Exchange rose at a meeting of the Chamber to voice the opposition of the coal interests to the project he was unanimously voted down. Petitions from the Chamber of Commerce and from the City Council went to Washington calling for further project funding, and Senator Thomas Bayne, whose home was at Bellevue on the cliff overlooking the lock, presented the petitions to Congress. General James K. Moorhead convened the 1879 meeting of the Ohio River Commission at the Willard Hotel near the White House in Washington, and he arranged for Merrill to be ordered to the capital to present his plans and demonstrate his models for the Commission and for the House Committee on Commerce.[21]

General Moorhead's campaign of 1879 succeeded in overcoming the opposition presented by coal shippers and Congress appropriated an additional $100,000 for work at Davis Island. The controversy of 1879 proved to be the last serious effort by rivermen and coal shippers to defeat project legislation. During the prolonged drought of the summer and autumn of 1879, low river flow blockaded the shipment of coal down the Ohio for months, apparently convincing coal interests that they should allow the experiment at Davis Island to proceed. In October 1879, John F. Dravo, founder of Dravosburg and the Pittsburgh and Connellsville Gas, Coal, and Coke Company, signed a Chamber of Commerce petition asking for full federal funding to complete the Davis Island project. As president of the Pittsburgh Coal Exchange and leading spokesman for the coal industry and towboat

operators, his signature signaled the end to organized opposition to the project. Dravo turned his attention thereafter to a campaign to secure a federally funded program condemning the property of General Moorhead's Monongahela Navigation Company in the courts and freeing that river of tolls, an effort which was successful in 1897.[22]

At the end of 1879, Colonel Merrill advised the Chief of Engineers he had observed a marked change of opinion among Pittsburgh coal shippers and rivermen. They had even expressed an interest in seeing the project completed at an early date. "I am now more firmly convinced than ever," Merrill said, "that the chief benefits to be derived from the construction of the Davis Island dam will be reaped by the shippers of coal."[23]

VI

CONSTRUCTION OF THE LOCK AND PASS

The work at Davis Island is so extensive and has received so much hostile criticism that I feel compelled to ask for such a reduction in my duties as will enable me to give it frequent personal attention. It is moreover a work that requires a constant study of details in order that it may fully come up to the latest improvements in movable dams.

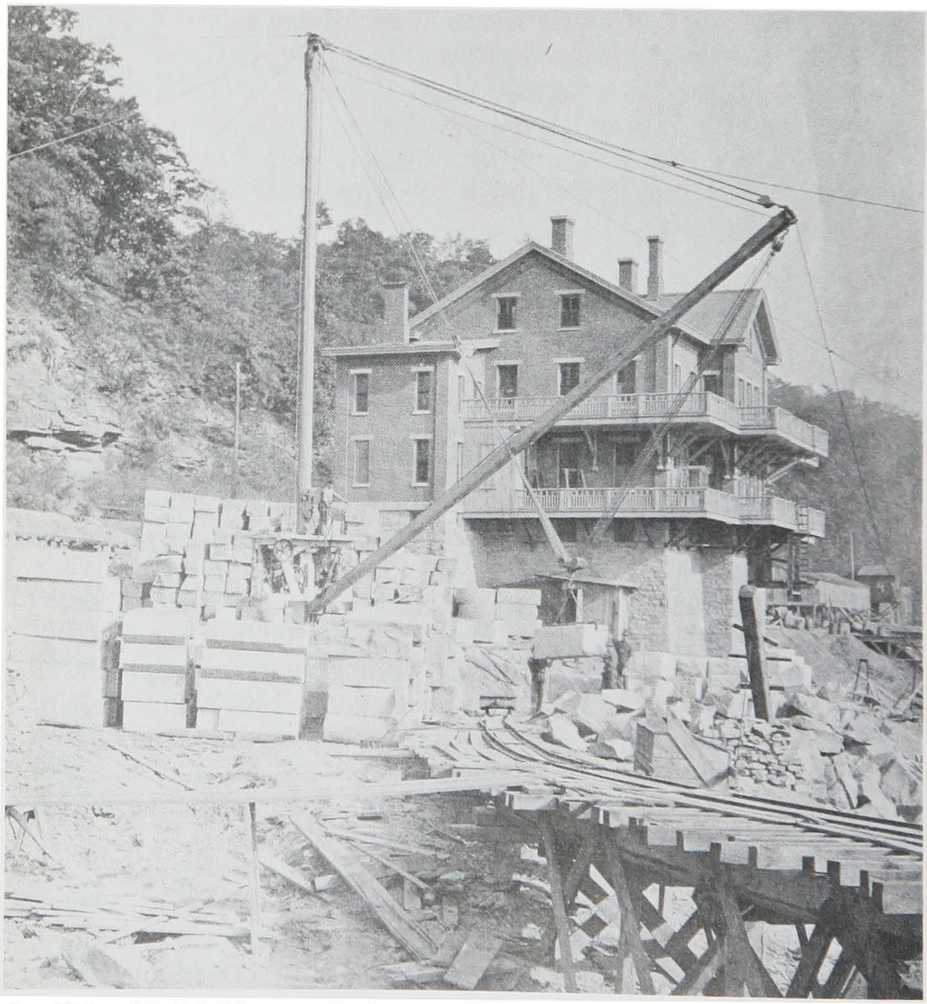
William E. Merrill, 1879

When requesting that another Engineer officer be sent to Cincinnati to assume charge of several waterway projects on tributaries of the Ohio, Colonel Merrill pointed out that the Davis Island project alone was sufficient to occupy all of his time. He was indeed overburdened, in charge of projects all along the 981-mile course of the Ohio and also on the Allegheny, Monongahela, Little Kanawha, Guyandotte, Big Sandy, Muskingum, Kentucky, and other tributary streams. Recognizing the merits of Merrill's complaints, the Chief of Engineers sent Captain James Cuyler to Cincinnati in early 1880 to open a second Engineer office in the Queen City which would become responsible for projects on several Ohio River tributaries. The new office eventually became the Second Cincinnati District, to distinguish it from Merrill's First Cincinnati District, and it operated until 1922 when the two Districts were merged.[1]

Thus freed from some of his responsibilities, Merrill was able to devote personal attention to the details and problems of the Davis Island project. He personally reviewed, for instance, the project cost accounting. In a letter to Lieutenant Mahan he questioned a bill from the steamboat *J. P. Thom* for towing an empty flatboat to the lock for \$5 and, on another occasion, a loaded flatboat to the lock for \$3. "If the charges were equal I would not be surprised," wrote Merrill,

"but to charge more for towing the empty than the loaded flat attracts attention. Please explain."[2]

Merrill gave special attention to the engineering design details critical to project performance. When a question arose concerning the length of chain needed to pull the rolling lock gates in and out of their recesses, Merrill penned a personal note to his friend George Dewey, the navy commander who later won fame at the Battle of Manila Bay in 1898, to ask his advice. Because boats on the inland rivers did not use anchors and chains, Merrill directed his question to Dewey, who had extensive experience with weighing anchor at sea. "How many turns," he asked, "ought a 5/8" chain to take around an 18" cast-iron drum so that it won't slip when pulling in a weight of 2 tons?"[3]



A stiffleg derrick lifts a stone for placement atop the rail car and movement to the lock's land wall. The completed lock house is in the background.

Carnegie Library of Pittsburgh, No. B-992

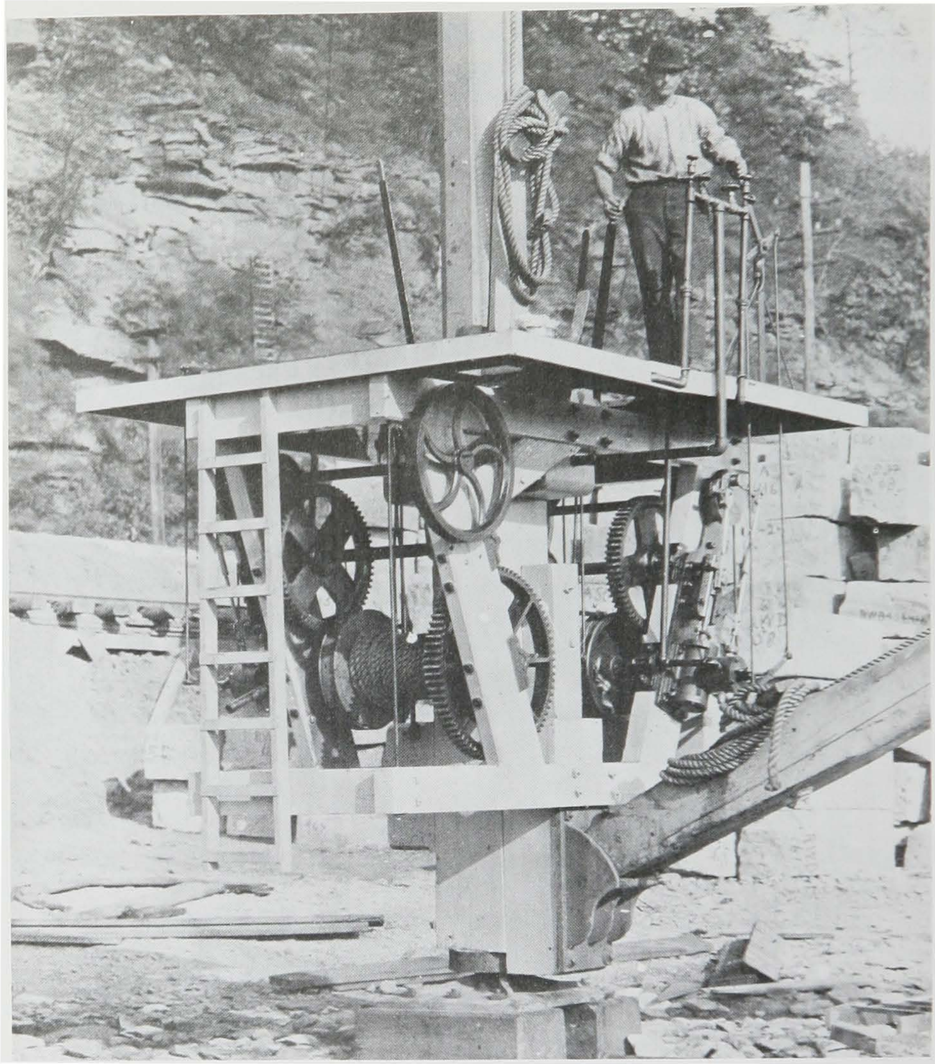
While the Colonel worried about the design details, Lieutenant Mahan used the 1878 and 1879 construction seasons to complete the stonemasonry lock walls. Except for the size of the lock walls, their construction involved little that was novel; engineers had been building with dimension stone since the Pyramids of Ancient Egypt were constructed or even earlier. Stone cutters at the quarries sawed blocks of stone weighing up to six tons from the faces of the quarries and moved them onto a barge or rail car for shipment upriver to the lock, where the stones were unloaded at a spot adjacent to the lock. Stiffleg derricks made of timbers, having a complex system of blocks and tackle to multiply the power of the men turning the cranks, raised the stones and placed them in the lock wall. In the cofferdams, stonemasons, chiefly of Irish heritage, placed the cement mortar atop each course of stones and pointed the joints between the stones, forming a watertight stone wall.[4]

Even working fourteen hours a day the work at the lock wall went too slowly, and Lieutenant Mahan and his chief civilian assistant applied mechanical power to the stiffleg derricks to speed the job. Through a system of gearing, they rigged up steam engines to turn the cranks on the derricks to raise and lower the stones. Six men operating a derrick by hand were able to lift sixty stones in ten hours, but four men with steam-power assistance could lift 150 stones in the same time, a 150 percent production rate increase.[5]

To further speed the pace of construction, Mahan installed electric lighting at the lock and began working a night shift also. He pushed the men and equipment to their limit to take full advantage of the few months of low water available during the summer and autumn of each year before the floods of winter filled the cofferdam. Equipment began breaking under the strain, and when a derrick buckled while lifting a heavy stone, Colonel Merrill intervened, establishing a safe maximum lifting weight for the derricks and warning Mahan: "All your plant has been worked too near its elastic limit, and is no longer safe, even if it were so in the beginning."[6]

Men also buckled under the strain, serious accidents occurred, and some died. During the course of construction, three men lost their lives at the Davis Island project; two were crushed at the stone quarries and a mason fell off the cofferdam into the river and drowned. No civil service or disability pensions, not even workmen's compensation, then existed to ameliorate the lot of workmen injured on the job, though Merrill did his utmost to help them by arranging for payment of their medical bills and by providing some with sedentary employment after their recovery, perhaps as night watchmen. Those were the customs throughout the construction industry during the 19th century.[7]

By the end of 1879, the lock land wall on the river bank with



A close-up of the operator, gearing, and steam piping of the stiffleg derrick used to move stone to the lock wall.

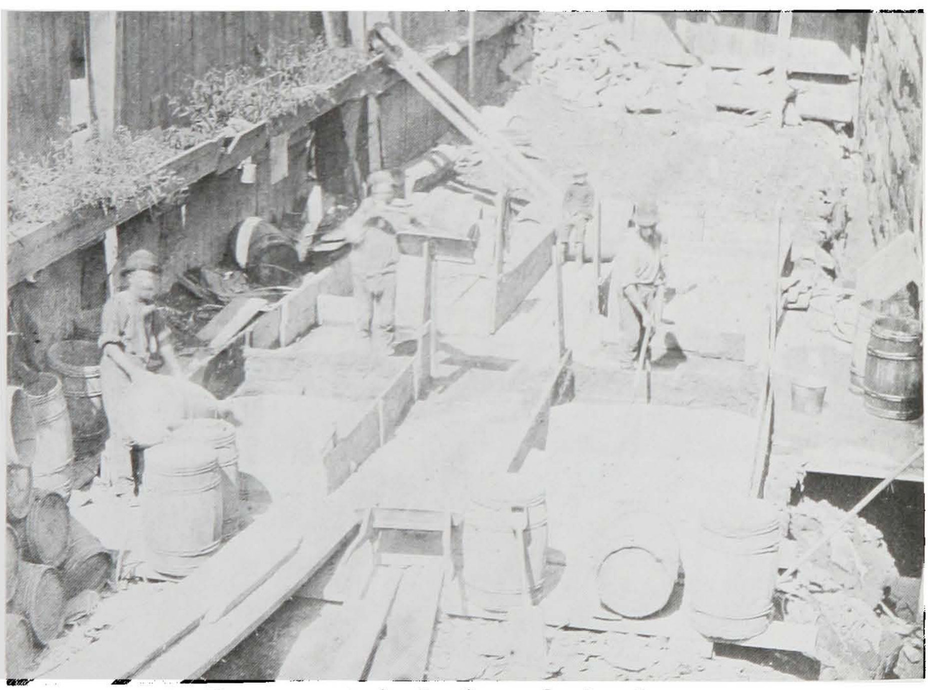
Carnegie Library of Pittsburgh, No. B-1000

its two gate recesses was completed and the time had come to begin building the river wall parallel to the land wall but 110 feet farther from the bank. Merrill sent the dipper dredges *Ohio* and *Oswego* to the site to excavate materials from the line of the river wall of the lock, thereby reducing the cost of subsequent removal of those materials by hand, and directed that the construction of the second cofferdam commence.[8]

When the cofferdam around the site of the river wall was completed and two ten-inch pumps emptied it of water, excavation of the mud and gravel began; but after going down fifteen feet it became

A rail car carrying a stone arrives under a stiffleg derrick, which raised the stone for placement in the lock wall next to the filling and emptying culvert.

Carnegie Library of Pittsburgh, No. B-1036



Workmen spreading concrete in the forms by hand.

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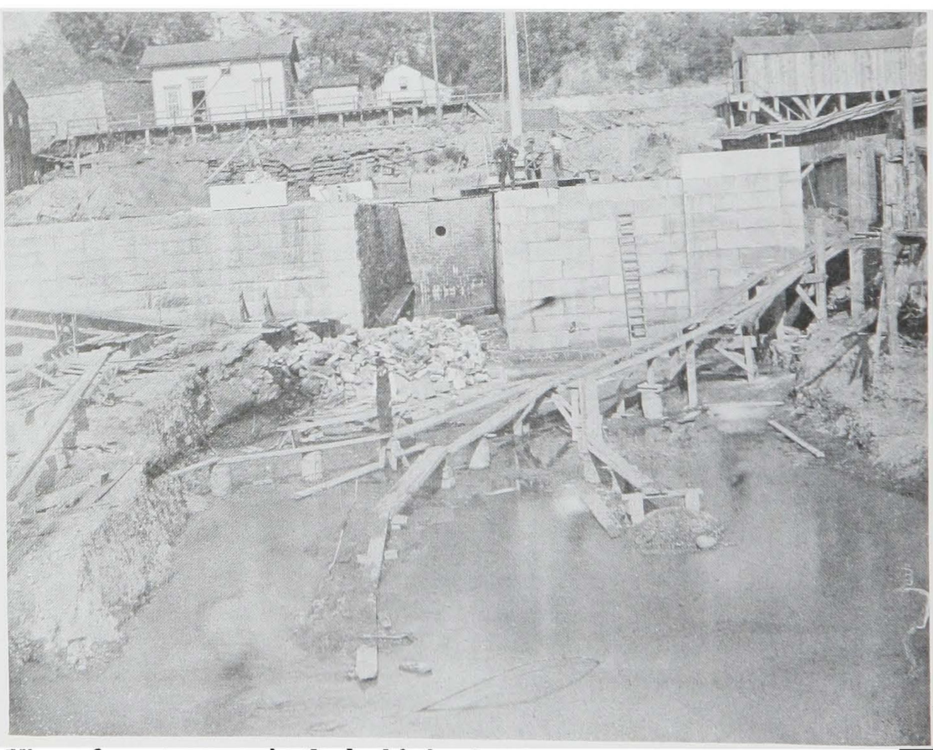
apparent the bedrock was too far beneath the gravel to provide a foundation for the lock's river wall. The steel rods driven into the gravel to find the rock during the earlier foundation exploration had struck hardpan, a cemented conglomerate of gravel, instead of rock. "The land wall of the lock rests inside the shore line of the ancient river," Merrill concluded, "while the river wall lies beyond the edge of the submerged cliff which bounds the ancient shore, and there is no other available foundation for it than the compact gravel that has filled up the ancient river bed." Because the land wall had already been constructed, the site of the lock could not be changed to a place where bedrock would be available, and it therefore became necessary to build a foundation for the river wall, an unexpected cost which would increase total project costs.[9]

Merrill and Mahan began assembling a concrete batching plant at the lock to build a foundation for the river wall atop the compact river gravel. They purchased a steam-powered stone crusher to break stone into sizes suitable for use as concrete aggregate, two concrete mixers of the type used by the Corps in the construction of the Washington Monument, hoisting engines to operate the derricks lifting the stone aggregate to the mixers and the buckets of concrete into



View of a gate recess in the lock's land wall, with ramps leading down into the cofferdam.

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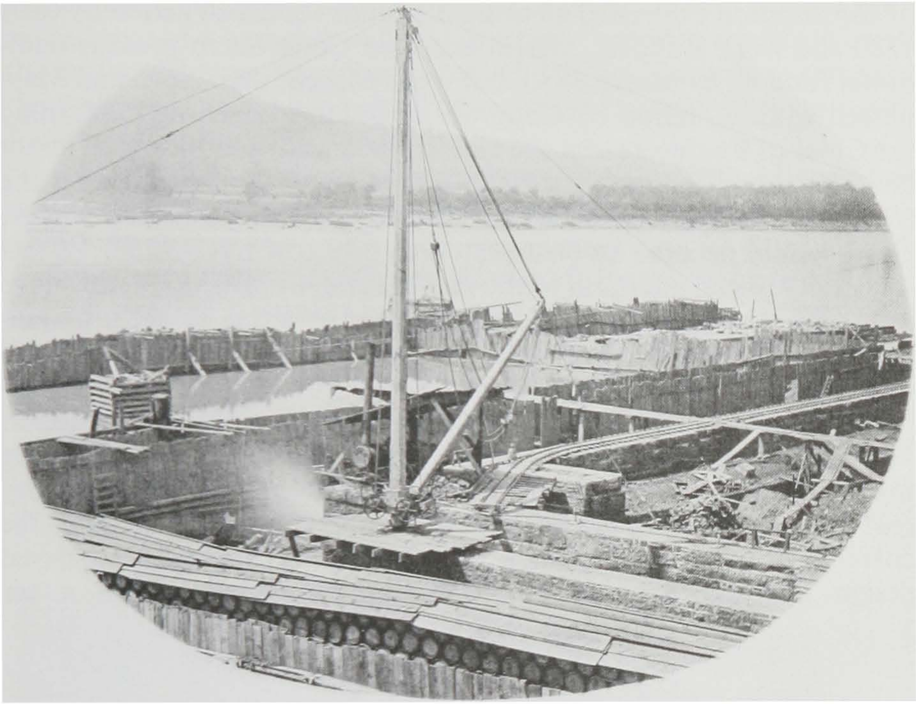


This 1880 picture shows a stiffleg derrick atop the gate recess with the river wall cofferdam in the background. In the foreground are stacked barrels of cement covered with boards.

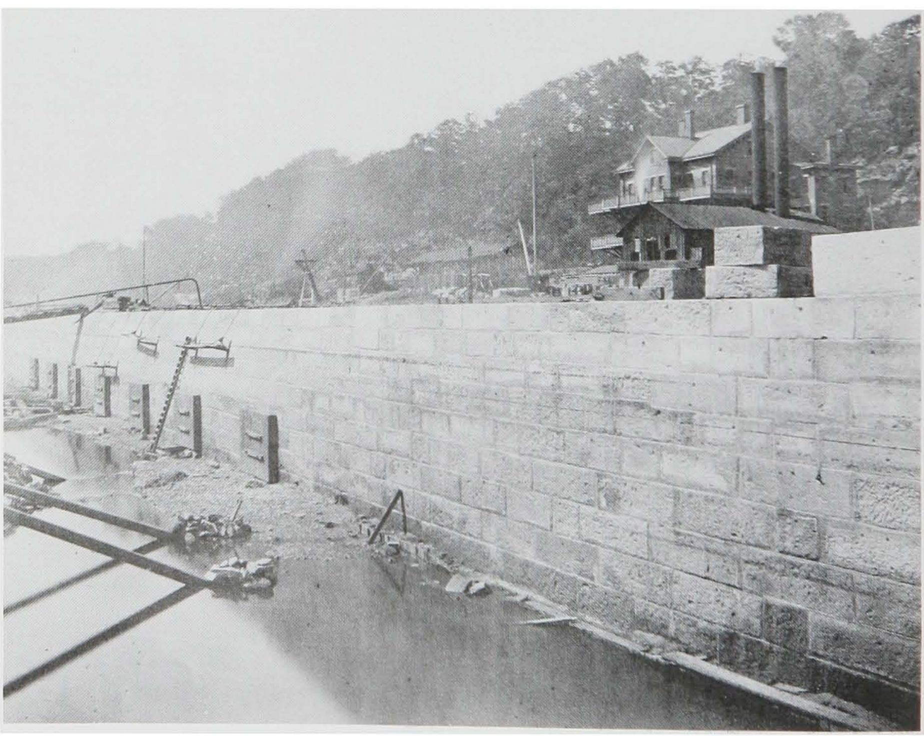
Carnegie Library of Pittsburgh, No. B-1035

the forms, and a battery of steamboat boilers to supply ample power for the steam engines. Hundreds of barrels of natural hydraulic cement were purchased to mix with the crushed stone and sand to form concrete, and Merrill also acquired a portable "materials laboratory" to test the concrete, for cement quality then was quite variable.[10]

After the mixers churned the aggregate and cement into concrete, the mixture went into large buckets atop small rail cars which were pushed along a temporary tramway to a derrick. The derrick lifted the bucket and poured the concrete into the space excavated for the foundation, or rather, placed it into the foundation, for the practice then was to use concrete with little moisture content, as dry as brown sugar. Workmen spread the concrete in layers a few inches thick and compacted it by manually raising and dropping heavy tamping rods. When completed, the concrete foundation for the river wall formed a block 694 feet long, 14 feet wide, and 12 feet and 8 inches deep. Once the concrete foundation was finished, the stonemasons entered the cofferdam and began laying the courses of ashlar masonry atop the concrete to create the lock's river wall.[11]

The extra cost of the river wall foundation and the rapid pace of construction exhausted all available funds for construction by early 1880 and work stopped. Merrill expected Congress to provide additional funding by March 1880, but when March, then April and May, passed without action by Congress he became concerned. Warning the Chief of Engineers that the entire 1880 construction season might be lost unless funding were made available, he pointed out that the cofferdam around the river wall had to be removed before winter, else it would become an obstruction to coal tow navigation. "I feel it my duty to call attention to the fact that the work which I now have in hand at Davis Island," Merrill declared, "is one of great magnitude and of great importance in the solution of the question of the radical improvement of our large rivers."[12]

Congress provided more funding for the Davis Island project in June and Merrill called back the employees laid off earlier, resuming night and day work at the lock river wall in July. As the stonemasonry rose higher course by course, the river wall became visible above the cofferdam, and rivermen soon objected to its battered, or tapered design. They wanted a vertical wall abutting the navigation pass, rather



The lock's river wall was nearly completed in this picture. The wooden frames on its side cover the seven filling culverts.

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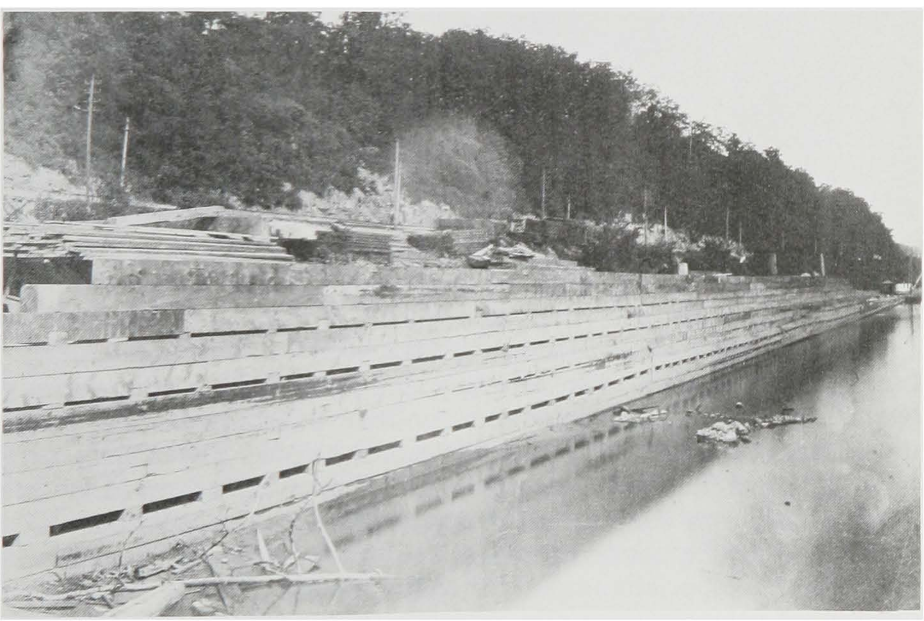
than one which grew narrower step by step as it climbed toward its full height. Telling Mahan that the cost of a vertical wall would greatly exceed that of a battered wall and that they therefore would stick with the battered design, Merrill commented: "If boats choose to rub along the wall when they have plenty of sea room outside, I see no reason for depriving them of the privilege."[13]

As the river wall neared completion in late 1880, Merrill drew up the final plans for the guide walls to be built along the river bank above and below the lock's land wall. Boats would tie to the guide wall while awaiting lockage and align with the entrance to the lock. Merrill ordered Assistant Engineer Israel V. Hoag and workmen on the Allegheny downstream to Davis Island to build the guide walls. Made of stone-filled timbercribs, the guide walls were set into the side of the river banks to align them with the land wall of the lock. Finished in 1881, the upper guide wall was 710 feet long and 15 feet wide and the lower guide wall was 250 feet long and 15 feet wide. (Years later, the guide walls were reconstructed of concrete and lengthened.)[14]



The upper guide wall was built of timbercribs along the bank upstream of the lock entrance.

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Wishing to keep some skilled workmen on the job during winter when high water prevented work inside the cofferdam, Lieutenant Mahan suggested to Merrill that they could begin fabricating the wickets and lock gates. He pointed out that the workmen laid off during the winter often found other employment and did not return

to the project during the following construction season. Concerned by funding shortages at the project, Merrill rejected Mahan's proposal, explaining: "There will be no trouble in procuring funds to finish with after the river is crossed, and our best policy therefore is to cross the river at once, and not to exhaust our resources on secondary matters."[15]

Workmen clearing the foundation inside the lock chamber.

Carnegie Library of Pittsburgh, No. B-1016

Colonel Merrill devoted to dam design the same personal attention he had given to lock design, spending countless hours poring over stream flow records and records of the soundings made to determine the depth of water over Horsetail Ripple where the dam was to be constructed. His goal was to design a dam at such an elevation that during dead low-water stages it would maintain a slackwater pool level with the six-foot mark on the gauge near Lock 1 on the Monongahela River. It was especially important that the sill of the navigable pass, over which river traffic would cross, be flush with the bottom of the channel. If the sill were too high, boats might strike it, damaging both the boats and the wickets of the dam; if too low, it might be covered by sand and gravel at the river bottom, interfering with the raising and lowering of the wickets. After lengthy study, he established the sill elevation at 693 feet above mean sea level, at a point where it would be safe from passing boats and still, when the wickets were up, provide six feet of water as a minimum in the Pittsburgh harbor.[16]

He also considered installing a Chanoine dam in the backchannel

to the south of Davis Island. His reasoning was that the wickets in the backchannel could be lowered in winter to create a current drawing floating ice down that chute, thereby allowing the remainder of the wickets in the main dam to stay up in winter. General Moorhead warned him, however, that drawing ice down the backchannel might damage boats frozen in the upstream pool, and Merrill therefore decided to build the backchannel dam as a fixed, timbercrib structure and to put the wickets of the main dam down out of the way of ice in winter. That was the way it was done on the Seine.[17]

Through monitoring technological advances in France and the progress of construction on the Kanawha River, where Colonel William P. Craighill had two Chanoine dams nearing completion in 1880, Merrill learned of a serious operating difficulty that he might avert at the Davis Island project by redesigning the dam. In the original Chanoine design, the wickets of the dam were lowered by moving a long iron tripping bar in the dam foundation to dislodge the wicket props and allow the wickets to collapse against the foundation. The tripping bars in France and on the Kanawha caused great trouble because they were constantly fouled by gravel and drift to the point that they could not be moved to lower the wickets.[18]

Merrill studied various means of eliminating tripping bars from the Davis Island Dam design. At the overflow weirs, it was relatively simple: the weir wickets could be both raised and lowered manually from the service bridge without using tripping bars. Because no boat traffic would go through the weirs, the service bridges could remain up in place at all times except when ice floes came downstream. The service bridge planned for the navigable pass could not remain up, however, for it would either delay traffic or be destroyed by the traffic. Master machinist J. R. Meredith suggested to Merrill that a traveler crane might be used to maneuver the wickets in the navigable pass. It could move along rails embedded in the dam foundation upstream of the wickets, with the dam tenders riding the crane to raise and lower the wickets. Merrill gave the traveling crane concept serious thought, and even redesigned the dam foundation to place the rails in the foundation as a back up system, but he preferred and adopted another system.[19]

After visiting Europe in 1878, Merrill had corresponded with various French waterway engineers concerning the technological advances they implemented. One was Alfred Pasqueau, in charge of the construction of La Mulatière Dam on the Saône River at Lyons. Pasqueau eliminated the tripping bars at that dam in 1879 through use of his invention called a double-stepped hurter, which was an iron plate with two slots in it that was embedded in the dam foundation beneath the Chanoine wickets. As a wicket was raised, its prop followed one slot to a notch in which the prop rested while the wicket was up.

When it came time to lower the wickets, the dam tenders aboard a maneuver boat pulled the wicket upstream, bringing the wicket prop to the top of the slot in the hurter, where it slid sideways into an unobstructed slot and followed that track down, allowing the wicket to fall freely to the foundation. That device allowed Pasqueau to make the navigable pass at La Mulatière Dam 340 feet wide, the widest open pass for boat traffic at French dams, and to entirely eliminate the troublesome tripping bars. Merrill was enthusiastic about the potential of Pasqueau's invention, and when the chief engineer of Belgium informed him the hurters would be used at dams on the Meuse River, he decided to use the hurter and maneuver boat system for operating the wickets of the navigable pass at Davis Island.[20]

Securing details concerning the Pasqueau hurters through correspondence with the inventor, he prepared revised plans for the dam. Pasqueau had taken out a patent on his invention in March 1880 in the United States, so Merrill went to Washington to discuss the plans with the Chief of Engineers. A royalty on the patent would have to be paid to Pasqueau, but Merrill insisted the invention was so useful that the royalty should be paid. He and the Chief of Engineers met with the Army Chief of Ordnance, who had considerable experience with patent matters and who advised that after many unfortunate experiences with patent cases it had become Ordnance policy not to pay inventors for patent rights until the cases were adjudicated in courts. The Chief of Engineers accepted that advice and ruled that Pasqueau would be paid nothing for the use of his invention in advance. After Merrill at Davis Island and Craighill on the Kanawha River installed the hurters in the dams, Pasqueau could sue in the Court of Claims, which would decide how much the royalty payment should be.[21]

Monsieur Pasqueau was not at all pleased that the Corps of Engineers would use his invention without paying the royalty he asked, and he warned that if he were forced into court he would substantially increase the amount to cover attorneys' fees. Merrill replied: "Americans, as you know, are very ingenious, and perhaps if you ask too much they will endeavor, as frequently happens, to avoid your patent by changes." At any rate, Merrill had no power to change the decision of the Chief, and he advised Pasqueau to wait until the hurters were installed on the dam and his patent actually infringed before bringing suit. Colonel Craighill, who had traveled to Lyons to see the Pasqueau hurter system, also adopted that system for the dams on the Kanawha River.[22]

Merrill redesigned the navigable pass at Davis Island to replace the tripping bars with Pasqueau hurters and also made other design modifications. The walkways for the weir service bridges in France were stored in sections near the dams and carried out for placement between the trestles after the trestles were raised, but Merrill decided

to hinge the metal walkways to the trestles in such a fashion that they would remain attached when the trestles were lowered and would lie atop the trestles when collapsed atop the dam foundation. In a letter to Pasqueau, he explained his reasoning for that design change:

> My experience as an officer of engineers, charged with the construction of military bridges, showed me the impossibility of using on our wide rivers any system consisting of many pieces which had to be brought from the storehouse. During the civil war we were obliged to ask the aid of several regiments of the line to transport the plank and beams to the bridge.[23]

Merrill prepared during early 1881 to build the first section of the dam, the 556-foot navigable pass starting at the lock's river wall and terminating at a masonry pier which would be built to separate the pass from the weir sections. Because the cofferdam surrounding the pass would block the main river channel during construction, Merrill was exceedingly anxious that it be entirely completed during the summer and autumn season of 1881. If it were not completed by December, when high water was expected and the Pittsburgh coal fleet departed for downriver markets, the cofferdam would block the passage of the fleet, perhaps reviving the quiescent opposition to the project. He made strenuous efforts during early 1881 to get all construction materials needed ordered and delivered to the site before spring floods receded and work began.[24]

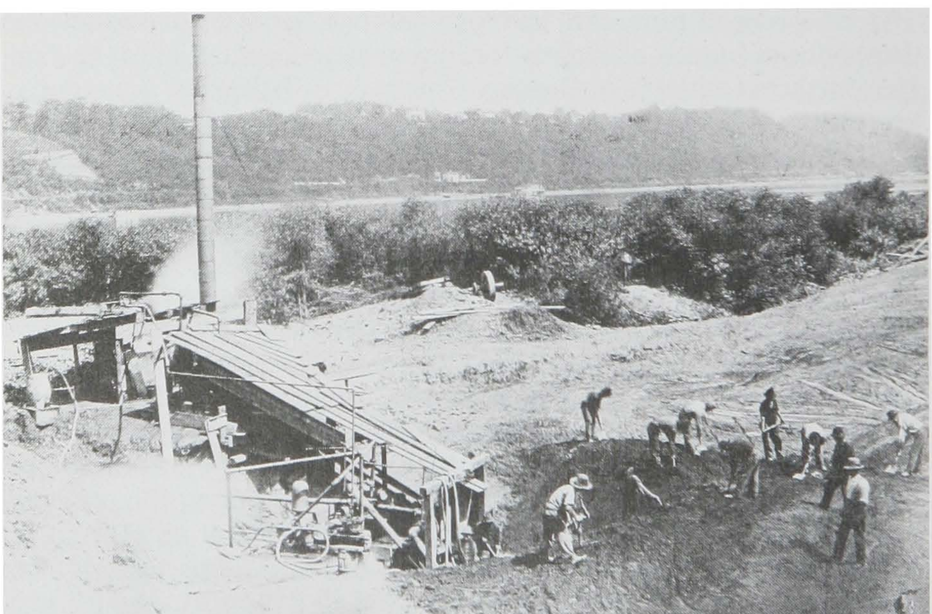
He ordered pine and hemlock lumber for the cofferdam and thousands of barrels of cement for the concrete foundation of the dam. He contracted with H. A. Ramsay Company of Baltimore to manufacture the wrought and cast iron frameworks for the wickets, the double-stepped hurters, the rails for the crane, and the wicket props — Ramsay subcontracted the forging of the props to Park, Long & Company of Pittsburgh. He ordered sturdy "Monongahela oak" for the wicket timbers, purchased a second concrete mixer to double production, had more derricks built, and had the battery of boilers moved onto a scow that could be moored alongside the cofferdam to furnish construction power. Everything that might be needed in the pass construction was delivered to the site and assembled in advance.[25]

Building the navigable pass in a single season promised to be the most critical phase in project construction, and at that juncture Merrill lost his most experienced engineers. James H. Harlow, the principal assistant engineer, resigned for higher-paying work as chief engineer of the Monongahela Navigation Company, and Lieutenant Mahan became so ill that he was hospitalized for five months. Merrill promoted William Martin to replace Harlow and arranged for the transfer of Lieutenant William M. Black to Davis Island as a replacement for Mahan. William Martin had been on the job since 1878 as assistant

to Harlow and Lieutenant Black had secured experience with Chanoine dam construction on the Kanawha River in West Virginia.[26]

To build the navigable pass, it first was necessary to surround the site with a temporary cofferdam. Two rows of oaken piling spaced twelve feet apart were driven into the river bottom, timber stringers were spiked into place between the piles, and planks were nailed to the stringers to form the two wooden walls of the cofferdam. The walls ran 612 feet from the lock wall into the channel, turned downstream about 237 feet, and then returned to the lock wall, enclosing a 3.5-acre area which provided space for construction machinery in addition to the dam foundation. Soil excavated on Davis Island formed the puddle filling the space between the two walls of the cofferdam.[27]

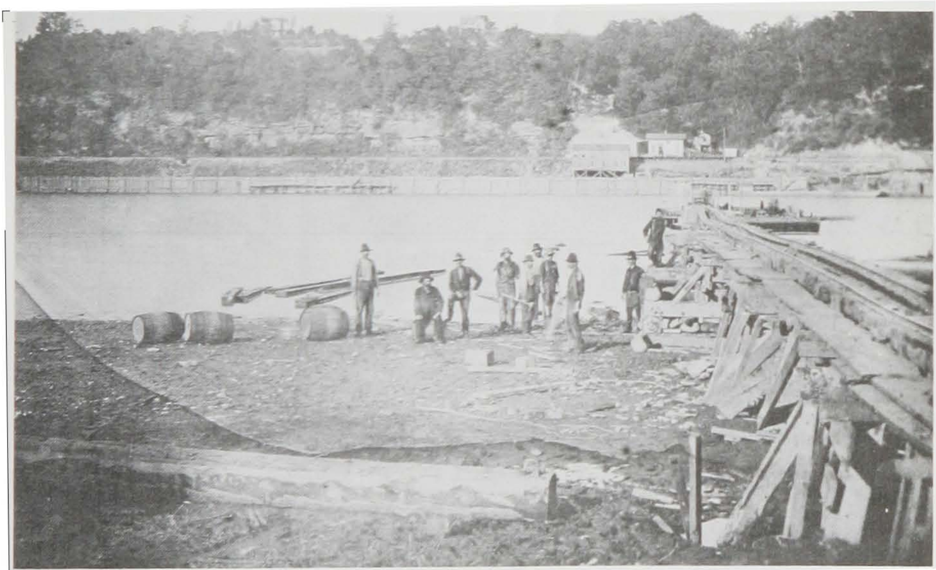
An advance in construction engineering occurred in connection with filling the cofferdam with puddle. Cofferdams around the lock walls had been filled with soil from Davis Island manually; that is, workmen shoveled the soil into small rail cars running on a tramway to the bank of the island to dump into scows for transport across the river to the lock, where workers shoveled it from the scows into the cofferdam framework, watering the soil to form mud and tamping it into place. Because time was short, William Martin and master machinist J. R. Meredith experimented with pumping soil from the island through a pipe into the cofferdam around the pass. First they



A steam pump sucks the mud of Davis Island and sends it through a pipe to fill the cofferdam with "puddle," while workmen shovel dirt into the vat at the pump's intake.

Carnegie Library of Pittsburgh, No. B-1001

tried without success a sand pump of the type used to excavate the foundations of the Eads Bridge, then a direct-action force pump, also a failure. At last they found a large centrifugal pump capable of forcing the mud puddle through 900 feet of four-inch pipe laid on the river bottom from the island to the cofferdam. Horses and mules plowed the island to loosen the soil, then dragged it in scrapers into a vat next to the pump, where workmen agitated it with high pressure water streams and the pump picked up the mud and sent it on its way through the pipe to the cofferdam. The pipe sometimes clogged and sand wore out the pump casing, but the puddle filled every crack in the cofferdam framework without additional watering and tamping by hand for settlement. Eliminating the double handling of the puddle by shovel and the transport by railway and scow across the river, the pumping system proved capable of delivering twenty-five cubic yards of mud per hour at a cost of $1.05 per cubic yard, saving both time and money. By August, the twelve-foot wide, twelve-foot high, and quarter-mile long cofferdam had been filled with 7,774 cubic yards of puddle and its interior dewatered to expose the river bottom.[28]



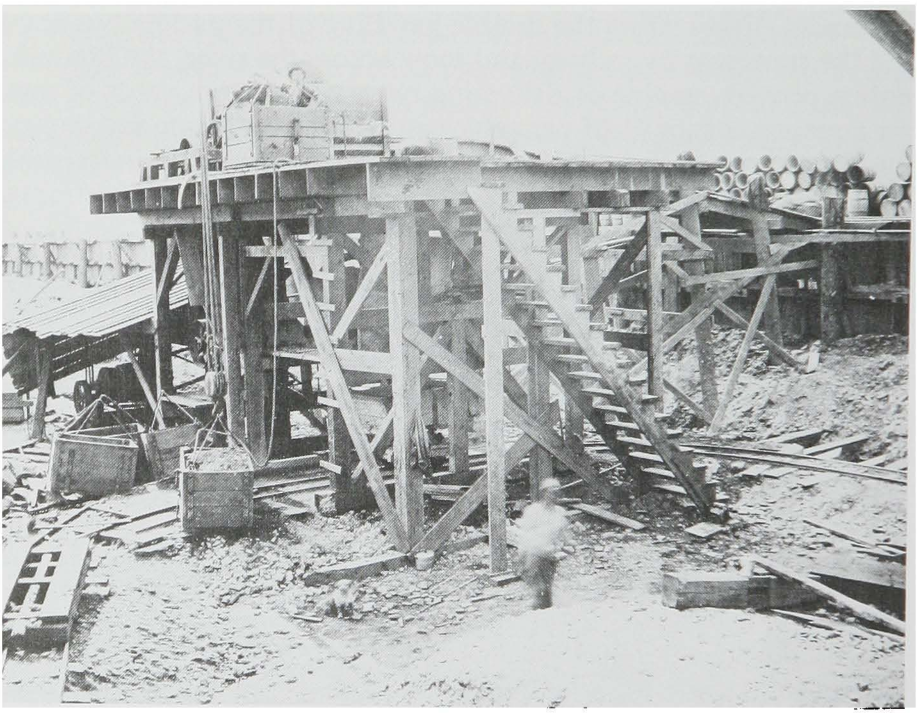
Workmen on Davis Island stand beside a tramway built to haul dirt from the island to scows for transport to the cofferdams.

Carnegie Library of Pittsburgh, No. B-1024

The second phase involved excavating a 600-foot trench in the river bottom gravel in which the concrete foundation of the dam would be placed. Without anchorage to bedrock and without piling driven into the bottom, the foundation essentially would float atop the gravel, depending upon its mass to hold it in place. "Bear in mind that the whole strength of the dam comes from the foundation and its resistance

by friction and inertia to motion," Merrill advised Lieutenant Black: "We therefore need a certain mass in any event, there being no rock within reach." In sum, he told the Lieutenant not to spare the concrete.[29]

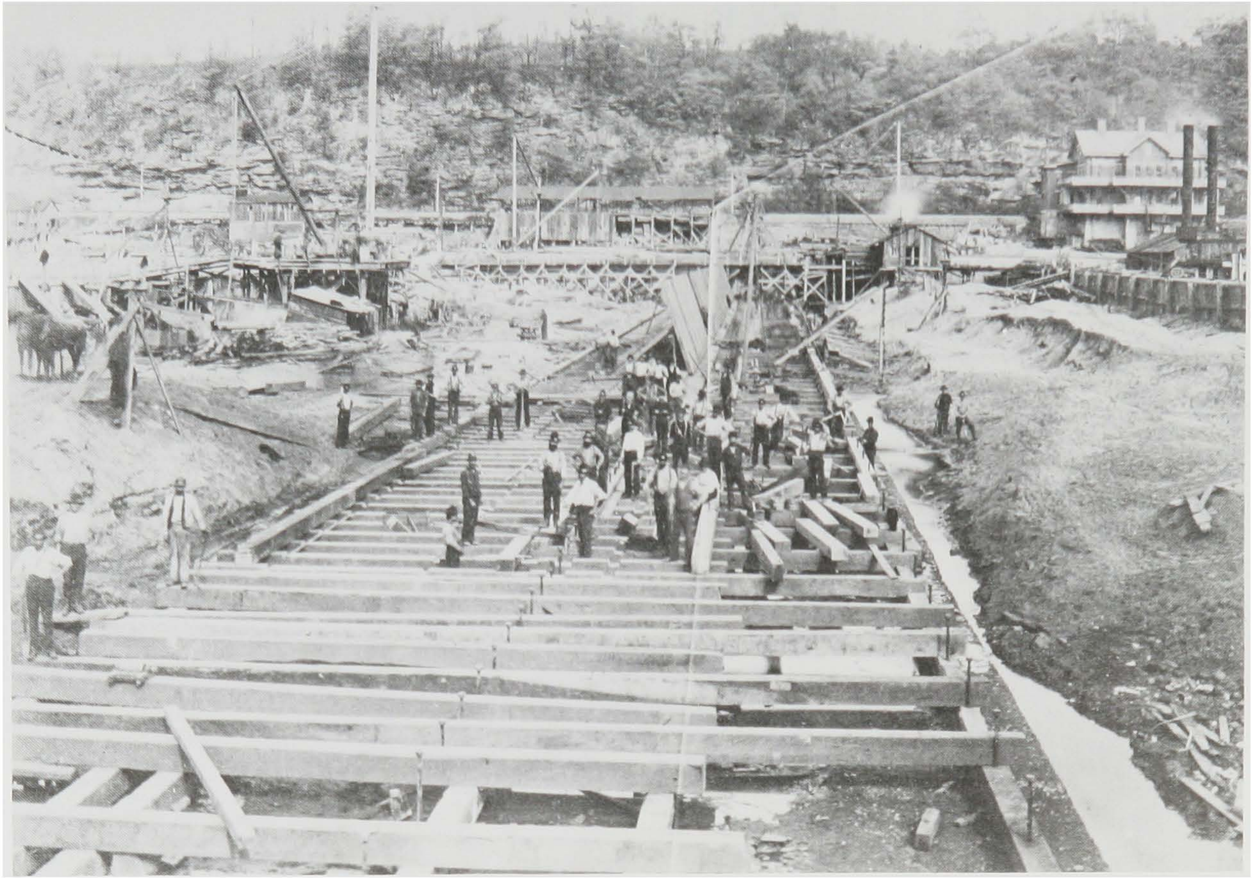
A derrick at first lifted the gravel out of the trench and swung it to the mixers, where the gravel became aggregate in the concrete that was returned to fill the trench. The derrick was unable to move the gravel as fast as required, however, and Merrill purchased a ladder excavator having an endless chain of buckets continuously moving on a track, the sort of excavating equipment that had been used by French



Derricks hoist buckets for placement atop rail cars which run beneath the Davis Island project's concrete batching plant. Note the workman and his dog in the foreground.

Carnegie Library of Pittsburgh, No. B-1017

engineers on the Suez Canal project during the 1860s. Constantly picking up gravel from the trench and moving it to the mixers, the ladder excavator accelerated the job, moving 12,424 cubic yards of gravel out of the trench and placing 6,453 cubic yards of concrete to form the foundation of the navigable pass. The massive concrete block ran nearly 600 feet along the river bottom and was 48 feet and 9 inches wide and 13 feet and 7 inches thick. A white-oak timber grillage was embedded in the concrete atop the foundation, and the anchor bolts for the wickets and hurters were installed in the timbers.[30]



Workmen installing the timber grillage to be embedded in the concrete of the foundation for the navigable pass in 1881.

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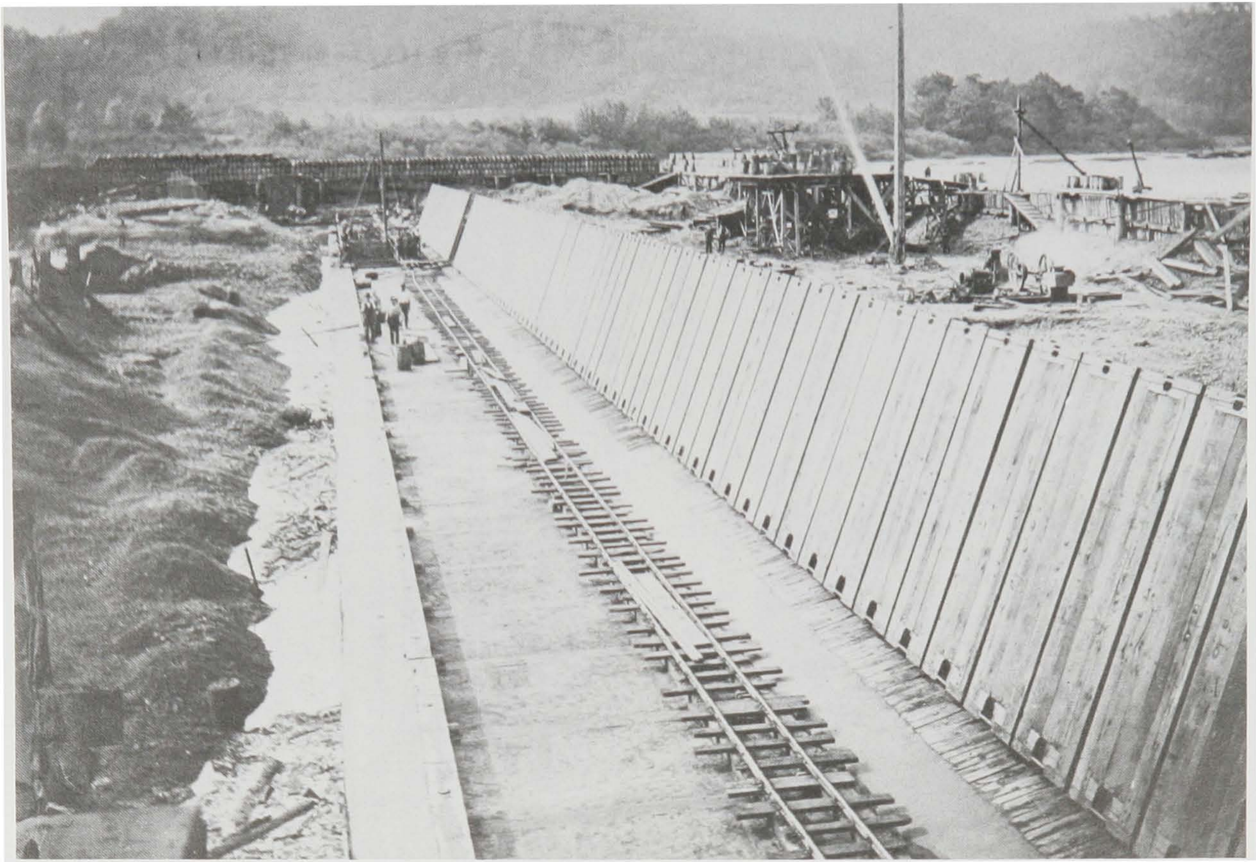
Installing the anchor bolts and metal work atop the foundation required considerable foresight, for Merrill had covered all contingencies in his design for the pass. He had adopted three redundant methods for pass wicket maneuvers. Pasqueau hurters were installed to facilitate raising and lowering the wickets from a maneuver boat, and that was the preferred operational method. In case the Pasqueau system failed, Merrill had rails embedded in the dam foundation along which a traveler crane might move to maneuver the wickets, and he also had the metal journals, to which the trestles of a service bridge could be anchored, placed in the foundation upstream of the wickets to use if necessary. Come ice or high water, he was determined that the navigable pass would always be open when the Pittsburgh coal fleet headed south.[31]

At ceremonies in September 1881, General Moorhead and the Ohio River Commission watched the installation of the first wicket in the pass. Installation of the wickets went smoothly thereafter with only a single complication: the design called for a navigable pass 556 feet wide, but the metal wicket framework was slightly larger than planned and the anchor bolts were set 4¼ inches instead of 4 inches apart, adding 34 and 3/4 inches to the total length of the pass and making its total length 558.9 feet. By Halloween in 1881, all 139 wickets

Members of the Ohio River Commission inspecting the raised wickets of the navigable pass inside the cofferdam in September 1881.

Pittsburgh District



By late 1881 all the wickets of the navigable pass were standing in place inside the cofferdam.

Carnegie Library of Pittsburgh, No. B-1010

The interior of the navigable pass cofferdam in 1881 with all the wickets collapsed atop the foundation. *Carnegie Library of Pittsburgh, No. B-1003*

of the pass were in place and the ashlar masonry pier to separate the pass from the weirs was completed, allowing removal of the cofferdam in November before it blocked the passage of the coal fleet. Supervising a double-shift working night and day at a frantic pace to complete the pass before the onset of winter floods, Lieutenant William M. Black had brought credit to himself at Davis Island. He left the job at the return of Lieutenant Mahan in December 1881 and went on to other duties in which he also distinguished himself, becoming Chief of Engineers during the First World War.[32]

VII

CONSTRUCTION COMPLETED

There is no longer any doubt that the Davis Island dam will do all that was ever claimed for it. On Friday, the marks here indicated five feet 10 inches or within two inches of the water claimed it would make, 6 feet. The only point yet to be settled is as to whether the wickets can be raised and lowered in a reasonable time; of this the officer in charge has little or no doubt.

Pittsburgh Gazette, 1884

During the first four construction seasons from 1878 through 1881, Colonel Merrill and his assistants completed the lock walls, gate recesses, lock house, and navigable pass, finishing the most massive and critical construction phases. The work remaining included building the three sections of Chanoine weir running from the end of the navigable pass to an abutment on the island along with the two masonry piers dividing the three weirs, constructing a timbercrib dam to close the backchannel south of Davis Island, and installing the rolling lock gates and the lock operating mechanisms. That work could have been accomplished in two construction seasons, perhaps even one. Instead, it required four seasons. Work had begun in 1878 with a $233,000 funding reserve accumulated from the project appropriations of 1875 and 1878, but completion of the navigable pass in 1881 had exhausted all funds on hand. Each year thereafter, Merrill had to limit the amount of construction undertaken to match the size of the annual appropriation. Given the funding he requested, which normally was at least double what Congress provided in annual appropriations, Merrill afterwards estimated that he could have finished construction in three years less time, and certainly the lock could have opened to navigation in 1883. It did not open until late 1885.[1]

Construction of the three weir sections began in 1882, proceeding in a sequence similar to that followed during construction of the pass. A cofferdam around the section was built, a trench excavated, concrete placed in the trench, wickets installed, and pier masonry laid. Rectangular in configuration and using Davis Island as one side, the cofferdam around the weir sections was 1,334 feet long, 12 feet wide, and 10 feet high. Effort was made to fill the cofferdam with puddle by pumping, but it failed because willow tree roots and other debris too frequently clogged the pipe; it was filled through manpower, running wheelbarrows along a ramp from the island onto the cofferdam framework to place 5,900 cubic yards of puddle. The character of the gravel foundation under the weir sections also differed from that found under the navigable pass, and excavating the trench with derricks and ladder excavator proved ineffective. Excavation was accomplished with a running dump, a temporary rail track in a circle from the excavation to the concrete mixers, around which small rail cars pulled by steam engines moved around the track, being filled, dumped, and returned empty to the excavation in turn.[2]

Placement of concrete in the weir foundation began in September and was completed in November 1882. The foundation of Weir 1 next to the navigable pass was a foot above the river bottom; the foundation of Weir 2 was two feet and of Weir 3 was three feet above the river bottom. While the weir wickets were the same 3 feet and 9 inches in width as those in the pass, they were shorter. The pass wickets were 12 feet and 1½ inches long, the wickets of Weir 1 a foot shorter, those in Weir 2 two feet shorter, and those in Weir 3 three feet shorter than the pass wickets. The metal framework and hurters of the weir wickets were attached to a timber grillage embedded in the top of the concrete foundation in a manner similar to those in the pass.[3]

Other dimensions of the three weir sections varied. Weir 1 nearest the navigable pass was 224 feet wide with 58 wickets and 28 trestles in its service bridge. Weir 2 also was 224 feet wide and had 58 wickets, but only 27 trestles, while Weir 3 was 216 feet wide with 56 wickets and 26 trestles. The full length of the main dam from the lock's river wall to the abutment on Davis Island was 1,223 feet, having a total of 305 wickets, each 3 feet and 9 inches wide with a three-inch space between each pair of wickets to prevent fouling when maneuvered. Though the Ramsay Company of Baltimore had supplied the metal work for the pass wickets, it lost the bid for the metal work in the weirs to the Pittsburgh Bridge Company. Just before the cofferdam around the weir sections was removed in November 1882, the workmen applied a coat of hot asphalt to the dam's metal work to protect against rust and corrosion.[4]

Built in 1883 to close the backchannel south of Davis Island, the fixed dam there was a stone-filled timbercrib structure of economical

construction and quite similar to the dams built to close backchannel chutes behind many other Ohio River islands as part of the open-channel, river regulation project begun in 1824. Its wide crest served, except at flood time, as a wagon ramp from the south bank of the river to the island. Because meager funding permitted little construction in 1883 other than the backchannel dam, Colonel Merrill reduced the construction force from its earlier peak of about 300 men to 152, including 3 blacksmiths, 4 enginemen, 5 machinists, 6 carpenters, 6 foremen, 124 laborers, and 4 teamsters.[5]

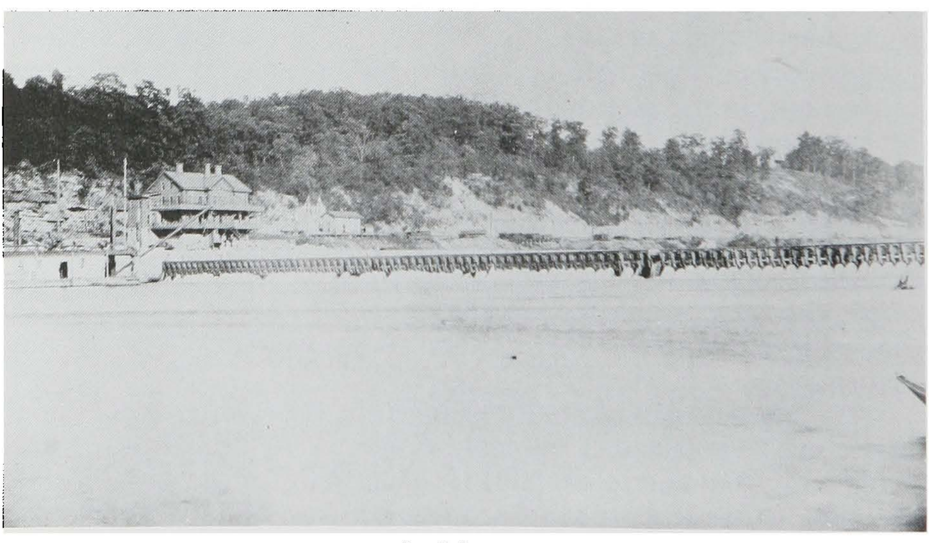
Action at the project in 1884 started with a bang on New Year's Day. The towboat *J. N. Buntin,* running at night with six coal barges, wrecked against Pier 1 between the navigable pass and Weir 1, and four of its crewmen drowned. The Davis Island construction force received severe criticism in the local press because the pier lacked a warning light and because the watchmen on the island had made no effort to rescue the crew of the *Buntin* from the river. The watchmen had no boat available for a rescue effort, a neglect Merrill remedied the following week with orders that skiffs be placed at strategic locations at the project. Joseph Walton, owner of the *Buntin,* sued because the pier had not been lighted, and though Merrill contended the crew of the towboat had been on a New Year's spree at the time of the accident, Walton eventually won a large award in the case. The dam piers thereafter were lighted at night, except when vandals stole the lanterns.[6]

Further troubles developed during the Valentine's Day flood of 1884, the highest of record on the Ohio to that date. While the river was flooding, the towboat *Alexander Swift* with six barges wrecked on Pier 1, the rushing water undermined and nearly washed away the backchannel dam, and the flood came close to eroding Davis Island itself, a dangerous situation because the island actually served as part of the dam. In the aftermath of the flood, several thousand tons of broken stone were dropped around the backchannel dam to protect it from further undermining and an earthen levee was constructed across the upper end of Davis Island to prevent future flood flows from crossing it; eventually the land behind the levee was filled to raise it above flooding. Arrangements also were made with the Signal Corps office, then responsible for forecasting the weather, at Pittsburgh for the resident engineer at Davis Island to receive daily flood warning reports.[7]

The project managers also changed in 1884. After a decade of service at Davis Island, Lieutenant Frederick A. Mahan was transferred and promoted to captain. He spent most of the remainder of his career with the Corps in Europe serving as military attaché and as a sort of resident student of European waterway technology. Merrill placed the chief civilian assistant, William Martin, in full charge of

finishing the work at Davis Island, because Mahan's successor lacked the experience needed to head up the Davis Island project. Lieutenant George W. Goethals reported to Merrill in full-dress uniform complete with epaulets in 1884, and Merrill had a frank discussion with him, telling him if he wanted to wear the uniform he could remain in the office for paper work, but if he wished to learn construction engineering in the field he would don work clothing. Goethals donned overalls, began as a survey rodman, then served as concrete foreman and construction foreman, but he worked at several projects along the Ohio, not exclusively at Davis Island. Goethals' biographers assert, however, that the practical experience he gained under Merrill's tutelage proved of great value to him when subsequently directing construction of the Muscle Shoals and Panama canals.[8]

When the river reached a low ebb in August 1884, testing of the Chanoine wicket dam began. A cofferdam built across the lock chamber, where the lock gates had not been installed, closed off river flow through the chamber, and the dam tenders began raising the dam for the first time. To raise the weirs, the tenders first winched in the chain attached to the service bridge trestles to pull the trestles up from the foundation, then attached the walkway from one trestle to the next. Running a winch out along a track atop the service bridge, the tenders caught the handle of each wicket and raised it to prop in place. Because the maneuver boat had not been constructed, the dam tenders placed their winch aboard a scow, moored it upstream of the navigable pass, caught the wicket handles with a boathook, and winched them up until the props on their backside lodged in the notch in the hurters to hold them in place. By September, all wickets of the dam were up and the



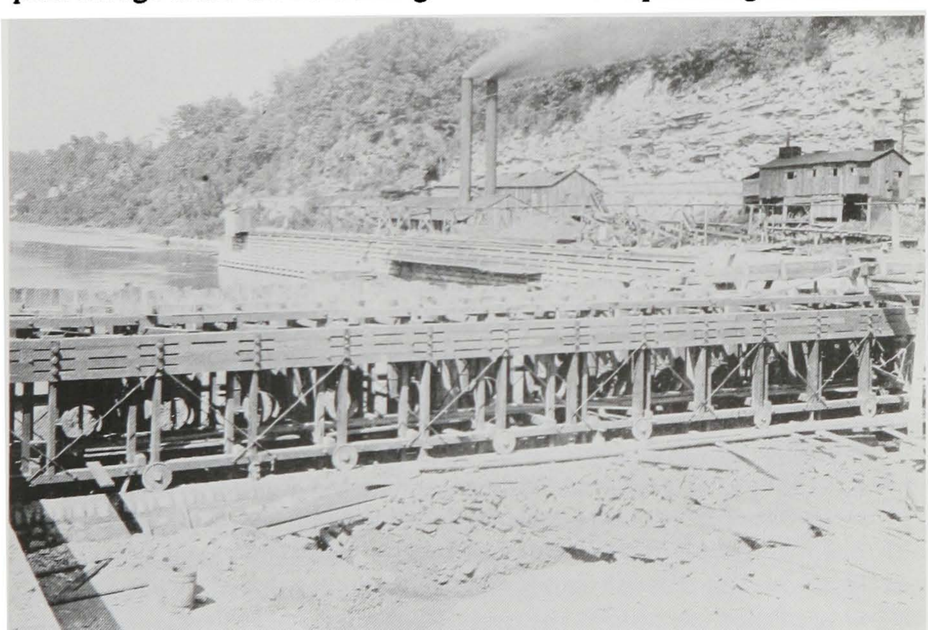
The wickets of the dam were raised in water for the first time in 1884.

Carnegie Library of Pittsburgh, No. B-1041-d

required six-foot depth had been achieved in the Pittsburgh harbor. For the first time at a low-water stage, steamboat packets left the pool of Monongahela River Lock 1 to enter the Davis Island pool and land at the Pittsburgh wharf.[9]

Wicket testing continued through September, the dam tenders alternately raising and lowering the wickets for practice. They learned the Pasqueau hurter system worked well except when stones lodged under the wickets to prevent their lying flat on the foundation. To deal with that exigency, Merrill ordered an underwater diving suit and armor for the dam tenders, who went down in the suit to dislodge the stones. The dam worked so well that after it was lowered and the Ohio returned to its customary October depth of a few inches, the coal shippers at Pittsburgh urged the Colonel to raise it again. He sent a telegraph to William Martin ordering it raised, but the start of winter rains made that unnecessary.[10]

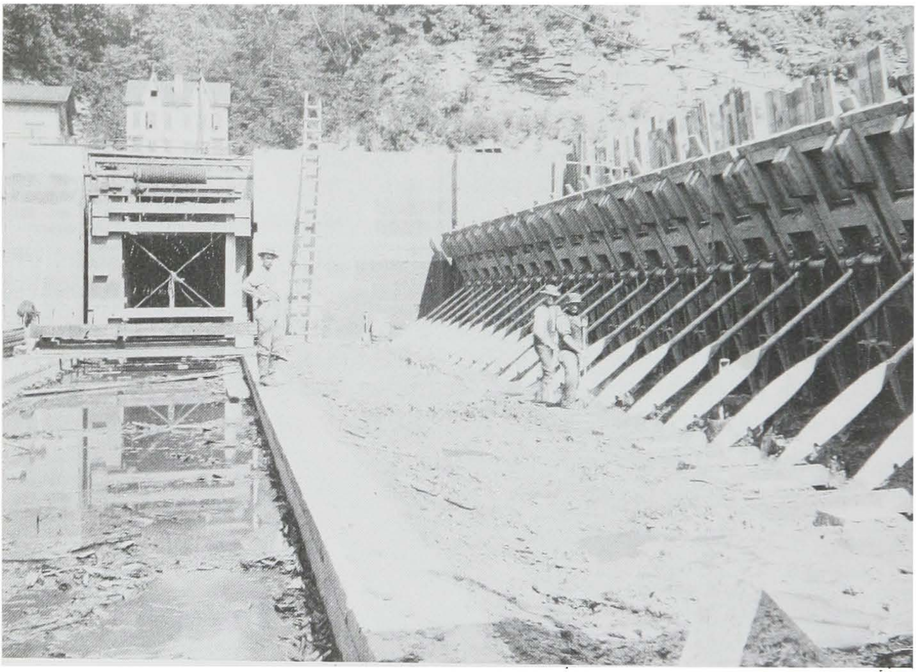
During 1884 Merrill awarded the contracts for fabrication of the lock and dam operating equipment and the maneuver boat. Scaife Foundry of Pittsburgh received the contract for manufacturing the machinery for operating the lock gates and the filling and emptying valves and Henry W. Oliver won the contract for furnishing the nuts, bolts, and washers, which were his company's specialty. For the two rolling lock gates, Merrill ordered 68,000 board feet of first-class white pine bridge truss timbers along with sufficient planking to make the



In 1885 the lower lock gate was installed in the chamber. Visible in the background are the lower guide wall, shop buildings, and the steam power plant building.

Carnegie Library of Pittsburgh, No. B-997

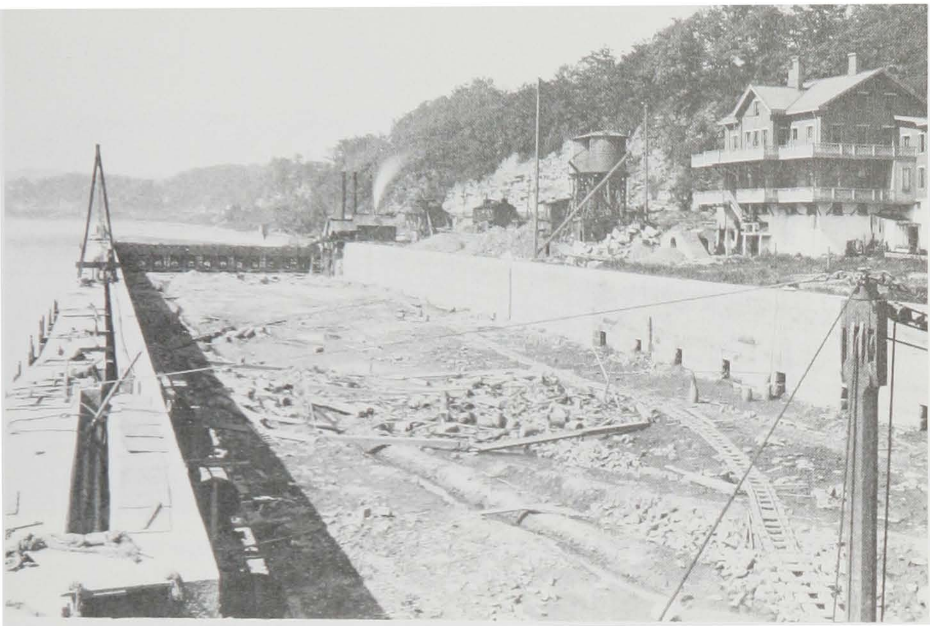
faces of the lock gates watertight. He had William Martin draw up the plans and specifications for the maneuver boat, furnishing him with copies of the plans for the maneuver boats used on the Seine for his guidance. The French maneuver boats were 30 feet long and 8 feet wide, while the boat designed by Martin was 36 feet and 1½ inches long and 10 feet wide, with a 2½-foot draft. Queen City Bridge Company of Cincinnati took the contract for building the boat for its low bid of $1,180, which included the price of a double-drum hoisting winch to handle the wickets.[11]



Resident engineer Frederick A. Mahan stands on the gate sill in front of the rolling lock gate, which sits in its recess with the drum and chain used to pull it out of the recess at the top of the gate. Two workmen on the right stand under the wickets which served as an emergency cofferdam to close the lock chamber.

Carnegie Library of Pittsburgh, No. B-1007

Though the Board of Engineers which approved the lock gate plans in 1878 had suggested that steam engines be used to pull the gates in and out of their recesses and also to open and close the emptying and filling valves, Merrill preferred to use the hydraulic power generated by the river through the use of a turbine of the type commonly used in grist mills at the time. Because the river might not have sufficient head to spin the turbine when the dam was down, he devised an elaborate backup system. When the turbine was spinning, it would power a pump to move water from the river up into two

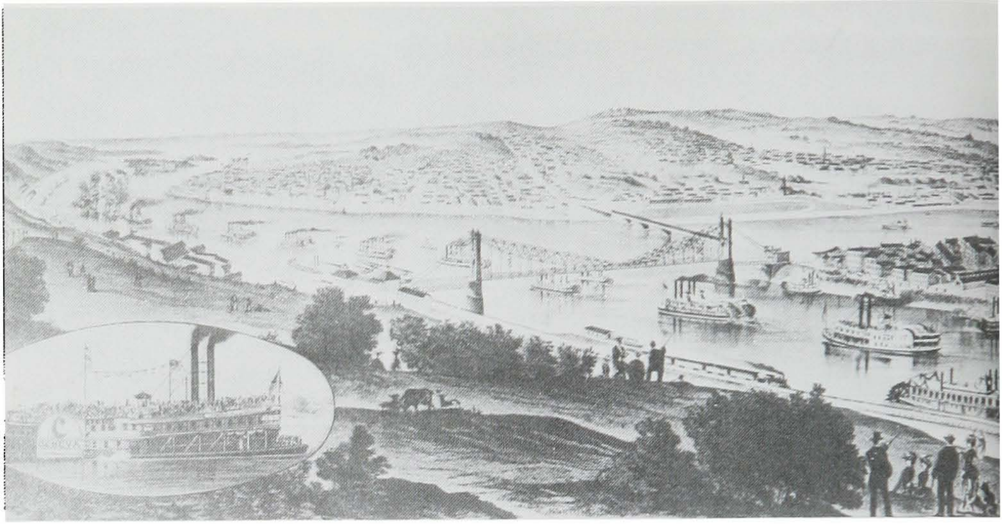


The interior of the lock chamber in 1885 with the lower lock gate rolled out across the chamber. Next to the lock house are the two water tanks furnishing power to the turbines which operated the gates and valves.

Carnegie Library of Pittsburgh, No. B-995

wooden water tanks on trestle towers of the sort used to replenish locomotive boilers. The system included a 25-inch-diameter turbine placed in the lock river wall, a pipe across the bottom of the lock to the pump, and pipes from the pump to the top of the water tanks. The tanks provided a reserve of water to spin turbines at each lock gate, the water dropping through pipes some sixty-two feet from the tanks to the turbines. As a redundant back up system, he also purchased a portable steam engine, albeit reluctantly. "One of my chief objections to steam," he told William Martin, "is the fear that at night, when there is little travel, the fireman will fall asleep & explode his boiler or let his steam run down so low as to be insufficient to do the required work." His fear proved well founded; several years later the steam engine boiler exploded, killing the dam tender.[12]

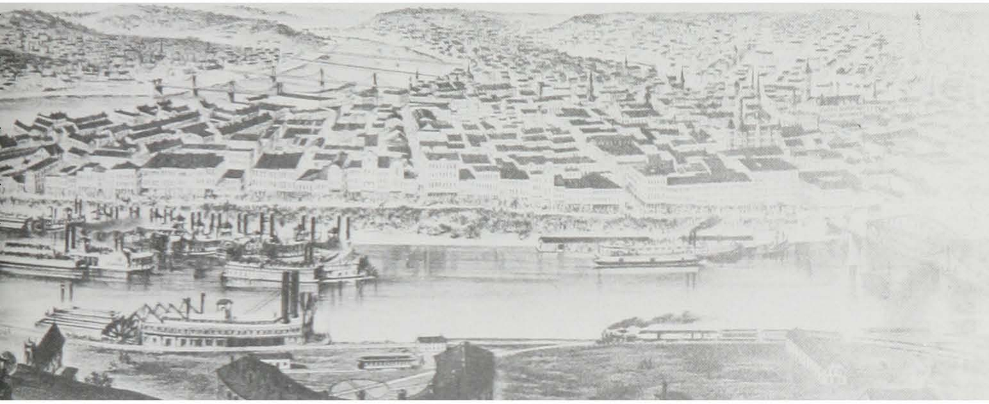
While the lock gates, valves, and various mechanisms were fabricated, assembled, installed, and tested during the summer of 1885, the Ohio River Commission and the Pittsburgh Chamber of Commerce planned elaborate dedication ceremonies to officially open the Davis Island project on the seventh of October. They asked Colonel Merrill to supply a list of the officers and civilians who had directed work at the project and therefore should be invited to the ceremonies as honored guests. Merrill named Horatio G. Wright, who had headed



Panoramic view of the steamboat parade leaving Pittsburgh's wharf and project. The flagship *Geneva* is shown on the left in the inset.

several of the Engineer boards which reviewed project planning and who had subsequently become Chief of Engineers, John G. Parke who had directed civil works for the Chief, and William P. Craighill, Orlando M. Poe, and Thomas Turtle who had served on the Engineer officer project review boards. He listed Captain Frederick A. Mahan and Lieutenant William M. Black and George W. Goethals. The civilians on the list included Israel V. Hoag, who had performed the site surveys and built the guide walls, master machinist J. R. Meredith, resident engineers James H. Harlow and William Martin, and George S. Kinsey, the draftsman who had prepared most of the plans. He did not list the European engineers who had guided him on his tour of Europe and whose inventions had inspired many of the features of the Davis Island project, but one French engineer, Emile Villier, did attend the dedication and expressed amazement at the size of the structure because he thought French engineers had built them as large as was possible with existing technology.[13]

While the Pittsburgh Chamber of Commerce made its arrangements for the dedication ceremony, workmen at Davis Island installed the lock gates and circular butterfly valves used to fill and empty the lock chamber, placed the turbine in the river wall to operate the pump, ran pipes from the pump to the water tanks atop the trestle towers, and ran pipes from the tanks down to the two turbines which would supply power for moving the lock gates and opening and closing the valves. Ten wrought-iron snubbing posts, five on each lock wall, were set into the masonry to tie off boats using the lock. William Martin rolled the lock gates back and forth across the chamber to test them, then removed the cofferdam blocking the lock chamber.[14]



heading down the Ohio (to the left) for the dedication of the Davis Island

Carnegie Library of Pittsburgh, No. A-501

Two days before the dedication, the dam tenders in their new maneuver boat went out onto the river to raise the wickets. At the time, the river was at its low ebb of October, and it required more than twenty-four hours for it to fill the pool upstream of the dam. When the pool level reached its six-foot stage at Pittsburgh on the day before the dedication, William Martin began testing the valves in the river wall, opening and closing them to fill and empty the chamber. During that testing, the pump which sent water from the river up into the water towers broke, and operational troubles therefore began even before the Davis Island Lock opened officially to navigation.[15]

The seventh of October was a Wednesday, but city government declared it a civic holiday and businesses closed to join in the celebration. During the morning, more than two dozen steamboats boarded passengers at Pittsburgh's Monongahela wharf. Colonel Merrill and the speakers for the occasion boarded the flagship *Geneva* commanded by Commodore Charles W. Batchelor, who had been a steamboat pilot since 1841. Also aboard the *Geneva* was Captain George S. Rowley, who had begun his career on the river as a keelboatman, pushing boats by hand all the way to Pittsburgh from New Orleans; Rowley had assisted W. Milnor Roberts with the 1867 survey of the Ohio and had later commanded the U.S. Snagboat *E. A. Woodruff.* His nephew James Rowley, who commanded the *Venus* in the parade behind the *Geneva,* was to live long enough to command the flagship of the steamboat pageant which in 1929 marked the completion of the canalization of the Ohio from Pittsburgh to Cairo.[16]

The parade organization somewhat resembled those of the

marches by town guilds on civic holidays in medieval times. The Pittsburgh City Council and Chamber of Commerce along with the Ohio River Commission boarded boats at the head of the parade. Behind them were boats carrying the Pittsburgh Petroleum Exchange, the Furniture Exchange, the Grain Exchange, and other industrial associations. Conspicuously absent was the Pittsburgh Coal Exchange. Bringing up the rear were crowded excursion boats carrying citizens who could afford the fares. Bedecked with flags, bunting, and banners, swarming with thousands of passengers, the dedication fleet made an impressive sight as the steamboats fired their boilers, the brisk October wind whipping clouds of smoke and steam over the river and a cacophony of steamboat whistles chorusing in celebration.[17]

Spectators lined the wharf, the Monongahela bluff, the bridges, and the hills along the river downstream of the Point. Trains carried crowds of passengers downriver to the lock until the number of people walking the tracks forced them to stop running. The press estimated the number of spectators at from thirty to fifty thousand, remarking that it was the largest crowd assembled at riverside in Pittsburgh since the regiments of volunteers had departed the city by river in 1845 bound for Mexico.[18]

At eleven that morning, Battery B, Pennsylvania National Guard, fired cannon at the foot of Wood Street, signaling the time for the fleet's departure. As Sergeant John Rial rammed the fourth charge down the mouth of the cannon, it detonated prematurely, tearing off his right arm and left hand. Flying through the air, the splintered ramrod spiked into the crowd, knocking a bystander unconscious and crippling a child. There being no electronic media at the time, only the crowd in the vicinity was aware the accident had occurred, and the celebration continued on schedule.[19]

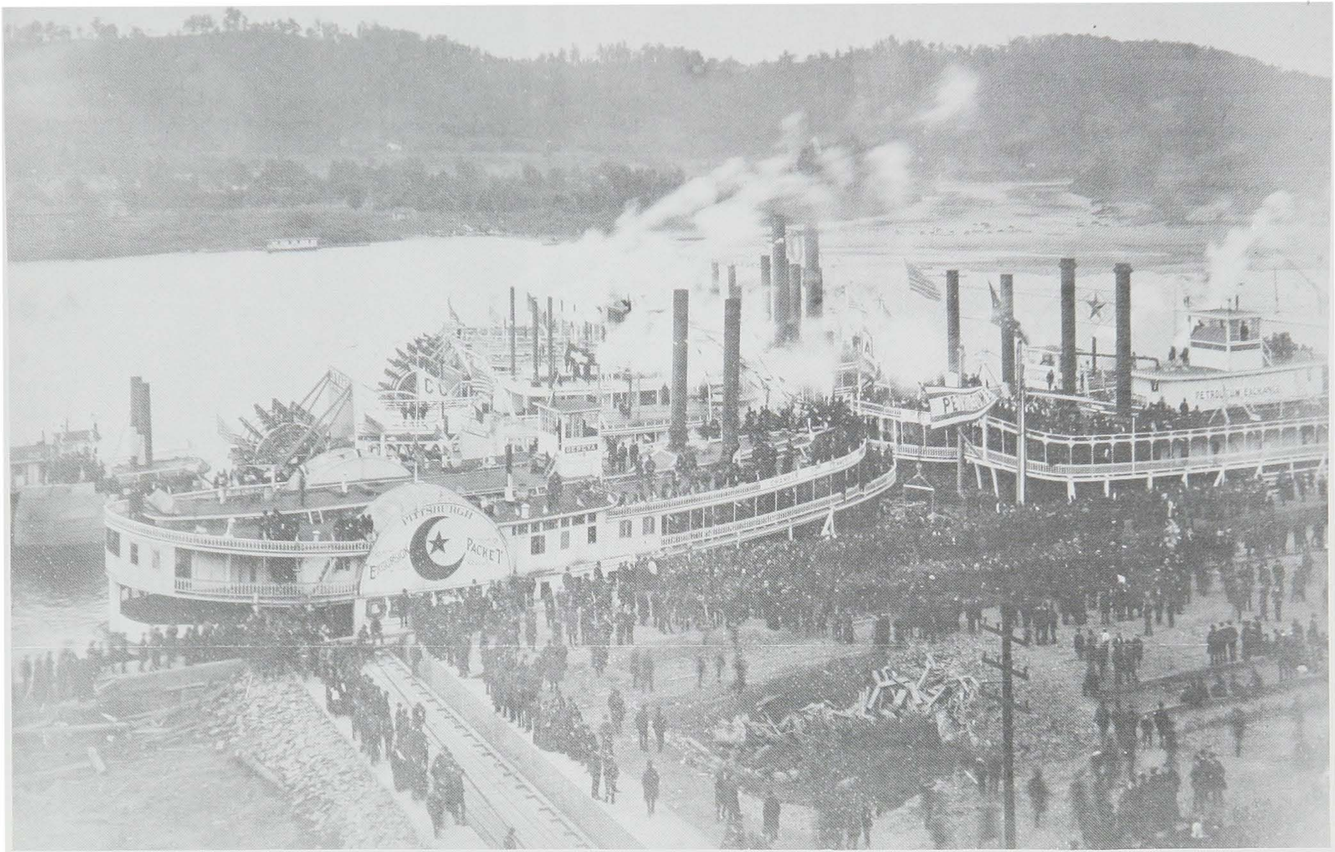
After the steamboats had assumed their position in the parade line, the fleet headed downstream on the five-mile trip to the Davis Island Lock, passing over Glasshouse Ripple, the first rapids on the Ohio that were now submerged by the dam's pool. On reaching the dam near the end of the noon hour, the captains blasted the boat whistles simultaneously, creating the greatest din, one reporter remarked, heard in the vicinity since news of General Lee's surrender reached Pittsburgh in 1865. Creaking and groaning, the new gears turned the axle and drum, winding the chain which pulled the giant upper lock gate back into its housing in the river bank and opening the lock chamber for entrance by the boats selected for the honor. The steamboats *Scotia, Elizabeth, Adam Jacobs, Batchelor, Robert Jenkins,* and *Geneva* entered the lock chamber to begin the formal dedication ceremony, with the speakers standing at the bow of the *Geneva.*[20]

Steamboats arriving at the Davis Island Lock on its dedication day in 1885.

National Archives, No. 77-H-62

Captain Batchelor explained to the crowd that, because the pump had broken, the lower lock gate would not be opened for the fleet to pass through to the river below the dam. He introduced Senator Thomas A. Bayne of Bellevue and former Congressman James S. Negley who had sponsored the legislation authorizing and funding the project. The principal orator for the occasion was Daniel Agnew, an elderly jurist from Beaver who had served as Chief Justice of Pennsylvania. Agnew delivered a spreadeagle address, describing Pittsburgh's industrial supremacy, castigating railroad monopolies, recounting the project's history, and praising: "Water, glorious water! Free as air, pure as the snowflake, refreshing as the dew dancing in the sunlight, and plentiful as the flow of Heaven." Agnew and the other speakers had much difficulty making themselves heard, for every time the locomotives stopped on the track behind the lock house sounded their whistles the steamboats at the dam tried to drown out that sound with their own.[21]

A tremendous burst of applause from the crowd greeted Colonel Merrill when he rose to speak. He began by expressing his hope that the celebration was merely the first of many to come that would squelch the old slur that the Ohio was dry all summer. Expressing his appreciation to the members of the Ohio River Commission for their loyal support of the project, he noted with regret that General James K.



Steamboats inside the Davis Island Lock on its dedication day in 1885. The speakers stood on the bow of the *Geneva,* the sidewheel packet in the left foreground. *Louisville District, No. 22575*

Moorhead had died in 1884 and had not lived to see the job finished. His special thanks went to the Pittsburgh ironmasters for their influential support, especially to Henry W. Oliver "whose bold and masterly tactics and lavish personal expenditures snatched victory from the jaws of defeat" in the Pennsylvania legislature in 1877. As a result of the hard work by Mahan, Harlow, Martin, and the other engineers assigned to the project, Merrill was able to assure the crowd that the lock and dam was of square and honest construction, well and truly laid. It was his son's twelfth birthday, and in hope that his son would live to tell the story in the 20th century, Merrill had him hoist the Stars and Stripes over the lock, officially opening it for business. "In the name of the United States," the Colonel concluded, "I now declare the Davis Island Lock and Dam to be open to navigation. *Esto perpetua.*"[22]

As the steamers backed out of the lock and the upper gate closed behind them, Merrill ordered a demonstration of the filling and emptying system. The discharge valves opened and the lock emptied of water, but because the pump had broken not enough water remained in the tank towers to open the valves and let water back into the lock. Asked why it did not operate as designed, a waggish newsman quipped: "It is because of the wicketness there." The following day, Martin had the pump repaired and back in operation, and a Pittsburgh newspaper with apparent glee reported that "an insignificant little market boat was the first of the river craft to pass through Davis Island dam. The honor intended for the Chamber of Commerce was captured by a boatload of cabbages."[23]

Colonel Merrill on dedication day announced that the cost of project construction amounted to $910,000, but several finishing touches then remained uncompleted. The final project cost figures footed up to $940,832.31, which included a small payment to the estate of Patrick Casey, one of the three workmen killed in accidents during the project's construction. Because Congress had not funded the project in such a manner that full advantage could be taken of every low-water construction season, the work had dragged on for seven years and thirty-nine days; Merrill was convinced he could have finished it in three years less time had adequate funding been available.[24]

From the initiation of planning in 1870 to the close of construction in 1885, fifteen years had elapsed — fifteen vital years of lost time. The delays resulting from the vigorous opposition from coal shippers and the towboat industry eventually cost those interests dearly. With full support from West Virginia coal interests, three locks and dams on the Kanawha River had been completed in the time it had taken to build one on the Ohio. By 1898 all ten locks and dams on the Kanawha River were in operation, allowing Kanawha coal easy

access to the Cincinnati and downriver markets where it offered formidable competition for Pittsburgh coal. Not until near the end of the century, when only the Davis Island Lock and Dam was open to navigation on the Ohio and only five of its 981 miles canalized to a six-foot depth, did Pittsburgh rivermen and coal shippers recognize that they stood to lose their trade to the Kanawha shippers and throw their unequivocal support to canalizing the entire length of the Ohio to a nine-foot depth.

VIII

EXPERIMENTAL OPERATIONS

In building the Davis Island Dam the engineer in charge had two objects in view. One was to improve the harbor of Pittsburgh, and the other, and more important object, was to demonstrate the only way of radically improving the navigation of the Ohio River. It was not to be expected that one movable dam would have any appreciable influence on navigation, but it could prove beyond cavil or misapprehension what a movable dam could do, how far it was adapted to the uses of the craft that navigate the Ohio, and how much it would cost.

William E. Merrill, 1885

Proving beyond cavil that the construction of similar locks and dams on the Ohio was warranted required that the Davis Island Lock and Dam be operated in such a manner that all doubts were extinguished. That task proved more formidable than expected. Operational problems at the project proved so severe that even Colonel Merrill had moments in which he questioned the wisdom of building more like it, but through structural modifications and revisions in operating procedures, the project was made to serve navigation for thirty-seven years. The experimental operations of Davis Island Lock and Dam and the structural modifications adopted on the basis of those operations had major influence on the design of the fifty locks and dams subsequently built on the Ohio and established the precedents upon which the operations of those fifty structures were established.[1]

Seven days after the project was dedicated in 1885, high water arrived and the dam tenders put the wickets down to open the channel for the Pittsburgh coal fleet, and they began to learn the hazards of their trade. Anchoring the maneuver boat at one side of the navigable pass while a diver went down for an emergency repair to

a wicket, the dam tenders watched the coal fleet pass. Hearing the pilot of the towboat *Barnard* signaling for passage, the maneuver boat crew hailed the pilot, warning him to stand clear, and heard an abusive reply. The *Barnard* and its barge tow grazed the maneuver boat, cutting its anchor cables and sending it spinning downriver; had the diver been underwater at the time, he would have drowned. Colonel Merrill called the United States Attorney at Pittsburgh, requesting the arrest of the pilot and seizure of the boat, but both pilot and boat were gone for New Orleans, out of the District, and the writ could not be served.[2]

During an unusually extended high-water period, the dam remained down until April 1886, and several problems revealed themselves when it was again raised. Floods had carried away even the cast iron covers over the lock machinery and had scoured out the gravel downstream of the dam, threatening to pull the gravel from beneath the dam's foundation and destroy it by undermining. Because the dam was movable with little fall over its crest, Merrill had not expected the sort of downstream scour that commonly occurred at fixed dams like those on the Monongahela, and he had not included in his design an apron of rock downstream of the dam to protect it against scour. To save the dam, barges loaded with stone were sunk along the downstream edge of the dam and stabilized with piling. Some 40,000 tons of stone eventually were dropped below the dam. That was lesson enough for the Engineers, and dams built on the Ohio thereafter had stone aprons and other protection against scour.[3]

Davis Island Dam, because of the unusually long periods of high water, was up only twenty-two days during its first fiscal year of operations, ending on the last day of June 1886. During that time, 14,015 boats went through the navigable pass and 314 went through the lock in 83 lockages. That brief experience with operations was sufficient to convince Merrill that his complex system of pumps, turbines, and water tanks for lock operation would not work satisfactorily, that the maneuver boat for wicket operations lacked sufficient power, and that he had underestimated the number of personnel and the cost of operations and maintenance needed to keep the project functioning properly.[4]

He had expected a permanent staff of five men to operate the lock and dam: Resident Engineer William Martin, Lockmaster James W. Riggs, Assistant Lockmaster U. Kidd Riggs, and two lock hands. He had hoped to employ temporary labor to supplement the permanent staff when maneuvering the dam became necessary. But he soon recognized that the complexities of operating the project were such that a permanent, experienced work force was constantly needed, and he increased the permanent work force to eight. When the dam was down, four were assigned to caring for the lock and four to the dam,

and when maneuvers were in progress all worked at raising or lowering the dam except one lock hand. He had originally estimated annual operating and maintenance costs at about $5,000 a year, but he increased that figure to $8,000 during the second year and it went even higher in subsequent years.[5]

Merrill essentially abandoned the complicated hydraulic lock operating mechanism after its first year of service. The amount of power developed by water flowing from the two tank towers to the turbines at each lock gate proved inadequate to start the gates rolling out of their recesses across the lock chamber, especially when the rail track on the bottom of the chamber was clogged with sand and gravel. He left the hydraulic system in place to operate the valves which controlled the filling and emptying of the lock chamber, but he geared steam engines to the drum shafts which wound the chains pulling the great lock gates in and out of their recesses.[6]

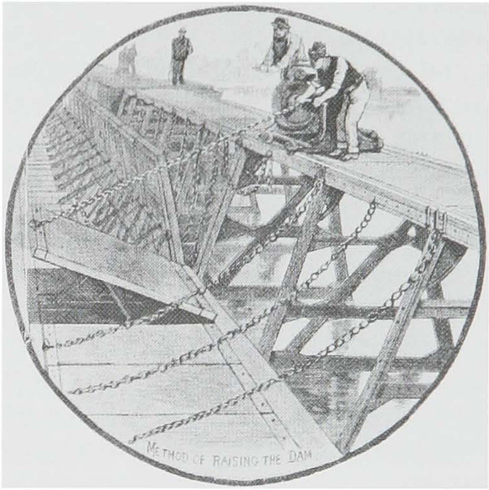
The first maneuver boat proved too small and underpowered. Too little working area was available for the crewmen and it had a manually operated hoisting winch used to raise the wickets; turning the cranks on the hoist to raise so many wickets quickly exhausted the energy of the workmen. Merrill put a larger flatboat in operation as a maneuver boat in 1886 and equipped it with a steam-powered hoist. The first maneuver boat then was converted to a needle flat, carrying the needles — four-inch square timbers — which were placed in the gaps between the wickets when river flow was so little that water lost

Dam tenders maneuvering the wickets at Davis Island in 1904.

Pittsburgh District, No. 327

through the three-inch gaps between wickets threatened to empty the upstream pool. The second maneuver boat served until 1895, when a larger boat with a steel hull fabricated by the Riter and Conley Company of Pittsburgh replaced it.[7]

While operating the rolling lock gates in 1886, Merrill discovered another design defect. The wheels on which the gates rolled back and forth across the chamber began breaking, and it became necessary for the lockmen to get under the gates to make repairs. Because only a foot of clearance had been provided between the gates and the walls

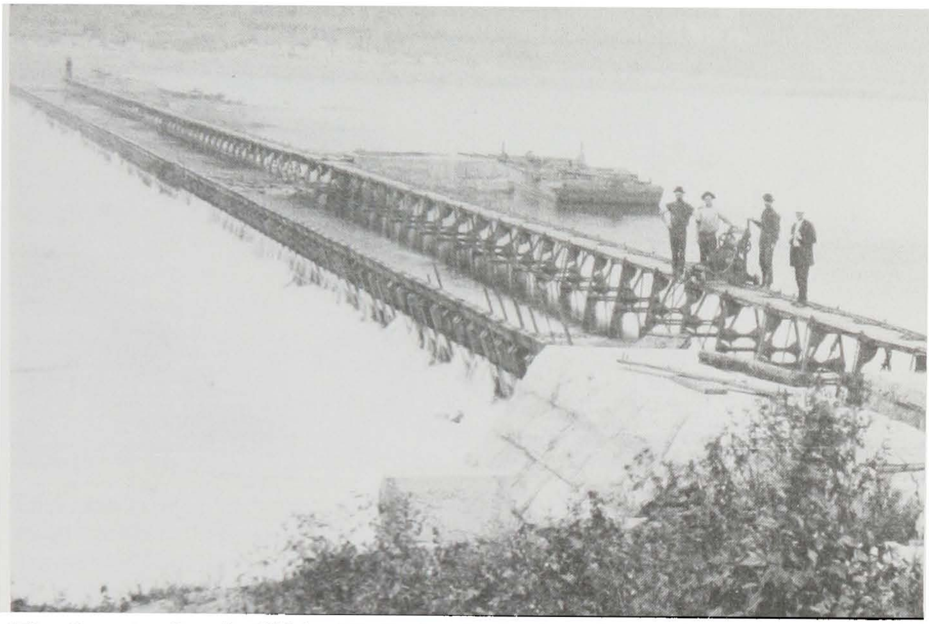


Dam tenders turning a winch atop the service bridge to raise the Chanoine wickets in the three weirs of Davis Island Dam.

Pittsburgh District

of their recesses, the lockmen could not block off the entrance to the recess, pump out the water, then slip down into the recess to work on the gate carriages; and therefore the entire lock had to be closed and the gates repaired while in the lock chamber. The lock design had included twenty-seven Chanoine wickets lying on the foundation at the entrance to the lock chamber to serve as an emergency dam to close the lock for repairs, but the wickets did not shut off enough river flow. The lockmen therefore had to construct a box cofferdam across the entrance to the lock of the sort used during project construction before they could pump the lock dry and enter it to repair the lock gate wheels.[8]

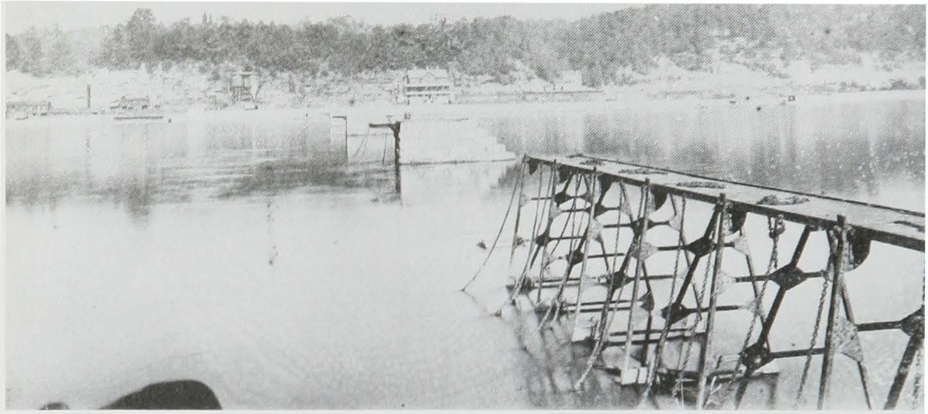
When the lockmen at last got under the gates to inspect the damages, it became apparent that the gate design had not provided adequately for stresses placed on the wheels when the pressure exerted by the upstream pool deflected a gate, forcing it an inch or two in a downstream direction. While the wooden gates could bend under



The dam tenders in 1884 with their winch atop the service bridge after raising the wickets of the weirs for the first time.
Carnegie Library of Pittsburgh, No. B-1041-F

the pressure, the metal wheels and axles beneath the gates could not: they snapped in two. Merrill and Martin first attempted to repair the gates with stronger wheels and axles, but the pressures then broke the rail tracks beneath the gates loose from their fastening in the foundation. After a decade of dragging the gates with broken wheels in and out of the recesses, efforts to repair them ended and they were replaced with gates made of steel. In the new gates, a Pratt truss replaced the original Howe truss and a pendulum suspension system allowed the new gate to deflect downstream an inch or so without causing stresses in the wheels, axles, and rails which carried them across the chamber.[9]

The service bridges which had served so well on the Seine for maneuvering the weir wickets proved ineffective on the Ohio, in part because the Davis Island Dam was downstream of Pittsburgh while the Seine River dams were upstream of Paris. During the 1880s, many homes in Pittsburgh converted from wood and coal to natural gas for heating, and lumber scraps, which once would have been scavenged for heating, increasingly ended up in the river, floating downstream to lodge against the service bridges of the dam. In June 1887, a cloudburst over the Allegheny sent a flood downstream which cleaned Pittsburgh and its suburbs of lumber and floatable debris of all varieties. Because the Pittsburgh telegraph office was out of service as the result of a fire, the lockmen at Davis Island received no warning of the flood's approach, and the service bridges and wickets were still up when the



The service bridge next to Davis Island is partially raised and the chains lead down to the weir wickets collapsed against the foundation. The masonry piers between the three weir sections stand in the river with the lock and lock house in the background.

Carnegie Library of Pittsburgh, No. B-1041-B

flood, carrying an immense quantity of debris, arrived. Piling against the service bridge at Weir 1, the drift destroyed the bridge. Drift destroyed the service bridge at Weir 2 in a similar fashion in 1888, and runaway barges subsequently damaged the bridge at Weir 3. The lockmen repaired the service bridge at Weir 3 next to Davis Island, but those at Weirs 1 and 2 were never replaced. The wickets in those weirs were raised and lowered with the maneuver boat thereafter, and service bridges were used only sparingly in the design for the dams built downstream of Davis Island on the Ohio.[10]

Because the usual river rises of November and December did not occur in late 1887, hundreds of loaded coal barges accumulated on the pool upstream of Davis Island Dam awaiting a rise to proceed downstream. Cold weather set in and ice formed on the pool, but because lowering the dam would strand the barges and damage them Merrill ordered that the dam be left standing, calculating that the damages caused by ice smashing against the wickets would be less than those done to the waiting fleet if the dam were lowered and its pool lost. The ice broke on New Year's Day of 1888, and ice descended upon the dam. The maneuver boat could not get to the wickets through the ice to lower them in the normal fashion, so William Martin hired a steamboat and barge, approached the dam from the downstream side, and rammed the barge's bow into the wicket props, forcing the props upstream and permitting the wickets to collapse. Great damage was done to the wickets and their supporting framework, but the project had won new friends among the diehard rivermen who opposed it.[11]

All opposition to extending the canalization project down the Ohio ended among rivermen after the summer of 1888. In July a record flood poured down the Monongahela River, carrying with it the wreckage of coal tipples and more than a hundred coal barges it had destroyed on the Monongahela. But the shippers with barges on the Davis Island pool were able to take advantage of the wide pool to escape the destruction, and not a single barge afloat on the pool went to the bottom. "It was a godsend that the Davis Island Dam had been up twenty-two days previous to the flood," one coal shipper proclaimed, "for otherwise not a boat or barge would have been saved from destruction, as the first boat adrift would have started others, and they in their turn the entire fleet."[12]

Towboats and thousands of coal barges collected in the Pittsburgh harbor awaiting a rise before departing downstream to New Orleans and other ports.

Pittsburgh District

Assured by coal shippers that the Davis Island project during the ice of January and flood of July 1888 had saved the coal industry from damages exceeding the entire cost of the project's construction, Colonel Merrill concluded that his experiment at Davis Island was successful. "In my judgment," he commented, "the time has now come for continuing the radical improvement of the Ohio River on the plans that are in successful operation at Davis Island." Merrill and a Board of Engineers began studying the extension of the project in 1890, and two years later Congress approved the construction of a second lock and Chanoine dam on the Ohio.[13]

Design modifications based upon operational experiences continued at the Davis Island project. Because drift destroyed the dam's service bridges, Merrill in 1887 decided to install a "drift chute" in the dam to pass the drift without wicket maneuvers. A beartrap chute built by John DuBois at Monongahela Dam 1 had failed, and so had a beartrap chute built by the Army Engineers in 1886 on the Kentucky River, but those had been very wide chutes aimed at substituting for locks to pass boat traffic through the dams. Merrill wanted only a narrow chute to pass drift through the dam, not one for the use of boats, and he still believed the beartrap system had potential. He designed a beartrap gate for the Davis Island Dam that was fifty-two feet wide and was capable of rising nine feet to block the chute through the dam. He decided to place the chute in Weir 1 next to Weir 2, removing the pier next to the navigable pass against which two towboats had wrecked and making all of Weir 1 part of the navigable pass.[14]

Construction of the beartrap chute began in 1888, when William Martin built a cofferdam around the site, pumped it out, and began excavation for placement of the beartrap foundation. Work was still in progress on Memorial Day of 1889 when terrific rains up the Conemaugh River and the failure of the Johnstown dam released a surprising flood down the Allegheny and Ohio. It overtopped the cofferdam, destroying the engines, pumps, derricks, and construction equipment along with the cofferdam. The flood receded as quickly as it had come, however, and Martin cleared away the debris and rebuilt the cofferdam, allowing completion of the beartrap in September 1889. Composed of two stonemasonry walls with the two overlapping wooden panels of the beartrap gate between them, the beartrap could be raised or lowered merely by turning valves which opened and closed culverts through the walls to the space beneath the wooden panels. When the valves were open, the water entering the space under the leaves caused them to rise into position to block the chute and hold an upstream pool; when the valves were closed and the flow of water beneath the leaves ceased, the leaves fell one atop the other against the foundation. The open beartrap sucked drift floating down the pool in its direction and passed it through the dam without lodging against the wickets. The beartrap proved an even more efficient addition to project design than Merrill had expected. The dam tenders found it more convenient for two of them in a skiff to row to the beartrap walls and open and close the valves to pass small rises than for seven of them to board the maneuver boat to raise and lower weir wickets. Its construction had also gotten rid of the dangerous masonry pier next to the navigable pass and had widened the navigable pass to 719 feet, fully ample for passage of the most unwieldly coal tows.[15]

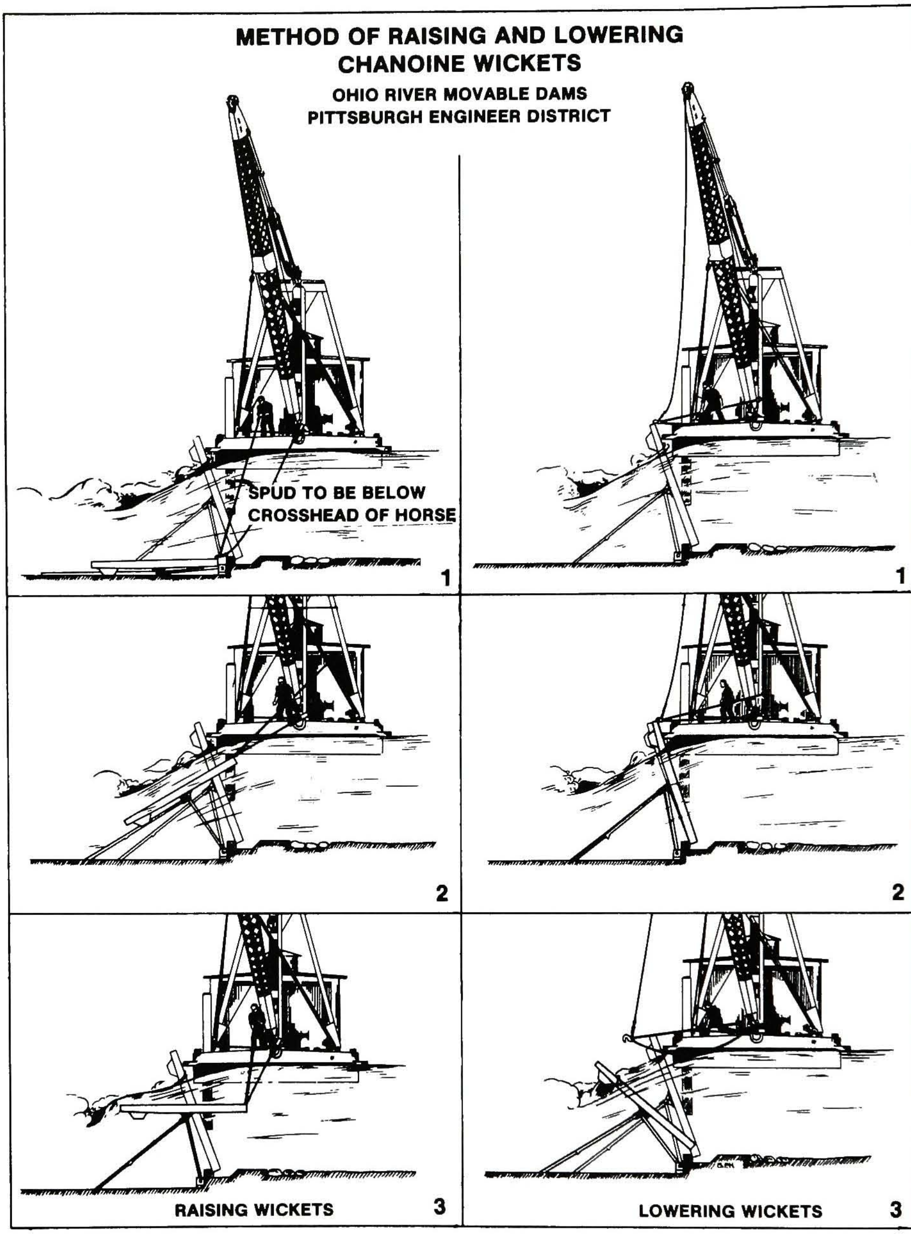
The operation of the beartrap gates was not entirely without accident. In July 1890, for instance, firemen in Pittsburgh pitched burn-

ing hay from a stable fire into the river, and it floated downstream to clog the culverts leading under the beartrap panels, shutting off the river flow and causing the leaves to collapse. When the dam tenders removed the hay, the leaves popped up with such force that they broke their restraints and wooden frames. William Martin had to build another cofferdam around the beartrap and repair it, but despite such untoward incidents the beartrap proved a very useful appliance; and the design of dams subsequently built on the Ohio commonly included two beartraps, each 120 feet wide.[16]

Gradually the operation of the project ceased to be experimental and became routine, handled by eight men, four assigned to the lock and four to the dam, supplemented by temporary labor when required. The lockmen lived in the lock house and the dam tenders in quarters built on Davis Island in 1891, the latter being an eight-room house painted olive green like the lock house. James W. Riggs was the first lockmaster and served until his death in 1889. His successors were U. Kidd Riggs, who resigned in 1894, and R. H. Riggs, Samuel Martin, George Y. Wefing, and James Bevington.[17]

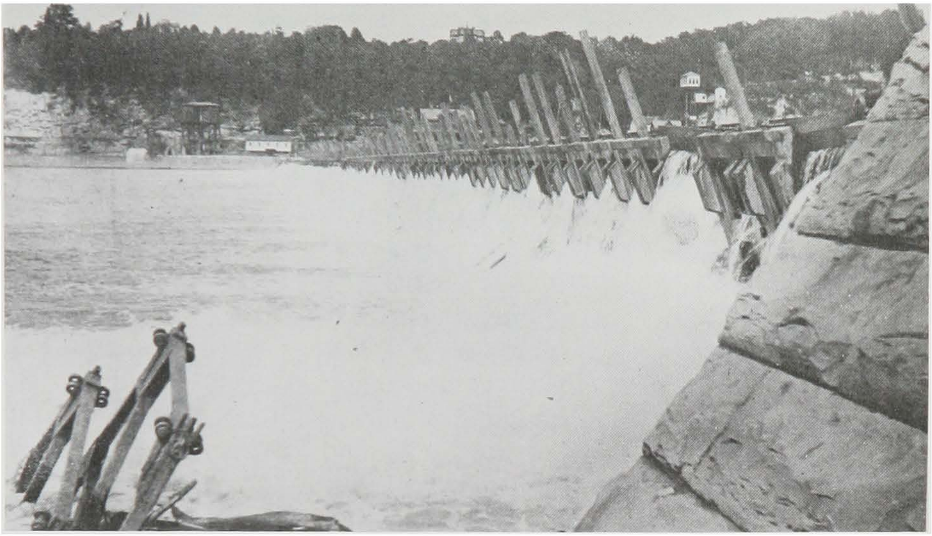
The routine operation of the dam began when the river was receding to a six-foot depth. Dam tenders boarded the maneuver boat and commenced raising the wickets of the navigable pass next to the lock, pulling one at a time up from the foundation and propping it in place with its hurter. After they raised the pass, they started on the weirs, which first were raised with a winch on a dolly atop the service bridges and subsequently, after drift had destroyed the service bridges, with the maneuver boat. When the wickets were up, they opened the valves at the beartrap and its leaves rose to block the chute. It generally took the crew eight hours to raise the dam and six to lower it. If a drought ensued and the pool fell below the desired six-foot depth at Pittsburgh, the dam tenders boarded the needle flat and again went across the river, placing the four-inch square timbers called needles in the three-inch spaces between the wickets. During extended droughts, they also dropped hay into the pool just upstream of the wickets, which sealed the tiny spaces between the needles and the wickets. The Davis Island Dam was up in place holding its pool during an average of 152 days each year.[18]

Once the dam was up, all boats passed through the lock, which under optimum conditions could be filled or emptied in four minutes. Water entered the lock through fourteen circular butterfly valves in the lock's river wall upstream of the axis of the dam, and it discharged through fourteen valves in the lower lock gate and seven in the lock gate recess. Several different power sources operated the lock gate valves over their years of operation because the Engineers used the project for experiments. Merrill's hydraulic power system, with water from the tank towers spinning turbines, proved inefficient during high



This diagram illustrates the steps by which the maneuver boat crews raised and lowered the Chanoine wickets of the dam.

Pittsburgh District



Timber needles closed the gaps between the wickets during periods of low river flow to help hold the upstream pool as shown in the 1891 picture. In the foreground on the right is the masonry abutment of the dam and on the left is the wreckage of a service bridge.

Carnegie Library of Pittsburgh, No. B-288

water stages and was frozen in winter. Steam engines replaced the tanks and turbines, but they proved unsuccessful because the steam condensed in the long pipes leading from the engines to the valves. Compressed air was tried, but it too was abandoned, for it tended to slam the valves open and shut, and at last a hydraulic oil system was devised that worked and which became standard at Ohio River locks.[19]

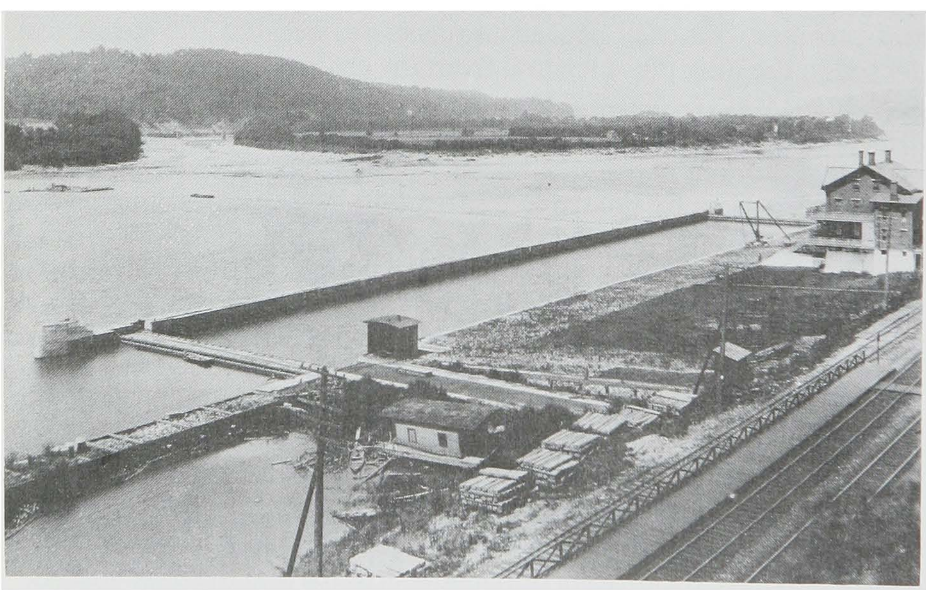
Carelessness by boat pilots often hampered project operations, for they sometimes ignored the rules of the road, smashing through the wickets of the dam and ramming into the lock gates. In 1891, for instance, the towboat *Nellie Walton* ran into the wickets of the navigable pass, laying them low, and the packet *Courier* dashed into the lock chamber under a full head of steam and rammed into the lower lock gate, causing extensive damage. "The conduct of the officers of this boat on many former occasions had been outrageous in the violation of the rules and regulations governing the lock, and this act is apparently their master stroke," wrote William Martin in his report of the accident to Colonel Merrill: "I would feel very much gratified to have the officers of the boat arrested and the boat libelled." Merrill contacted attorneys for the Department of Justice, and eventually the owners of the *Courier* paid for the damages to the lock gate.[20]

Merrill had not considered recreational boat traffic in the project planning, but after operation of the lock began he had to make

a decision about how the small craft were to be locked, there being no Corpswide policy on the subject at the time. He decided that the ponderous lock gates should not be operated, and worn out, to open for every rowboat that came along, and, with approval from the Chief of Engineers, he restricted lockage of recreational craft to three times daily, unless they could get into the lock chamber with a commercial boat. He also recommended to the Chief that the owners of recreational craft who used abusive language in their discourses with the lockmaster be denied use of the lock altogether until they made suitable apologies, but the Chief did not approve that recommendation.[21]

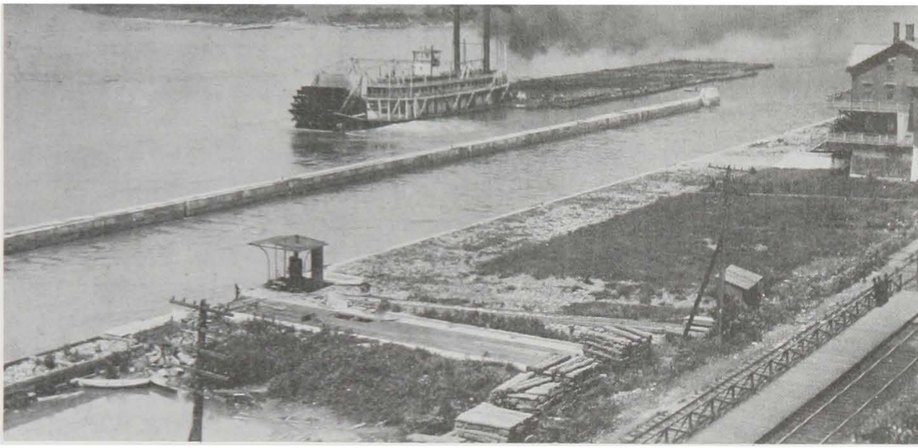
Large numbers of recreational craft were afloat on the pool of the Davis Island Dam not long after it was completed, and at times they made the lives of the lockmen and dam tenders miserable. "We are annoyed by owners of small steamboats and pleasure yachts landing at the service bridge or at the Island end of the dam," William Martin complained, adding: "These boats are used principally by idle persons and for the purpose of carousing they come to Davis Island and by their orgies make the night hideous." He was instructed to contact local law enforcement authorities and have the most obnoxious pleasure seekers arrested.[22]

As recreational use of the Davis Island pool increased, a steamboat excursion company proposed to build an amusement park on



Davis Island Lock and Dam with both rolling lock gates closed and the dam raised. Visible at the crest of the dam are the timber needles placed between wickets to help hold the pool. The head of Neville Island lies beyond the dam, and to the left is the toe of Davis Island.

Louisville District



Coaltows crossed the dam through the navigable pass at higher water stages without using the lock. Note that the lock chamber also remained open at those stages, with the gates rolled back into their recesses in the bank.

Louisville District

Davis Island, and the village of Bellevue overlooking the lock asked about developing a small community park at the upstream end of the lock. Because the proposed amusement park on the island might interfere with dam operations and because other steamboat excursion companies could demand equal access to the island, the Chief of Engineers denied a permit for the park. Bellevue's request for a community park was granted, and William Martin filled and graded the area behind the upper guide wall for use as a park by Bellevue citizens. The town graded and bricked a road through a ravine down the cliff to the railroad tracks, and people often gathered in the park at riverside on hot summer afternoons, where it was a bit cooler than elsewhere in those days before air-conditioning.[23]

Because the snagboat and dredging fleet seldom ascended the river as far as Pittsburgh, the workmen at the Davis Island project also were made responsible for minor channel clearance work in the pool and a few miles downstream of the lock. To test theories concerning boat propulsion, William Martin designed and built at his own expense a small steam-powered launch with a screw propeller. Colonel Merrill was quite pleased with the fast little boat and soon purchased one for use at the lock transporting materials and the channel clearance crew. Under the command of Inspector S. H. Fowler, the speedy little

Wenonah patrolled the upper river for years, generally carrying explosives to remove obstructive rocks and wrecked coal barges from Horsetail and Merriman's ripples and the chutes at the Trap and Deadman's Island. While trying to assist the crew of the towboat *Emily Jung* in 1911, the *Wenonah* was run down by the towboat *James Moren*. Lockmaster R. H. Riggs saved himself by jumping from the *Wenonah* to the deck of the *Moren* and two other men managed to swim to safety, but James Dickey was sucked under the *Moren*'s tow and drowned.[24]

Safety records were not then maintained, and the number and frequency of personal injuries occurring during the operation of the Davis Island Lock and Dam is not known. The only other fatality mentioned in the records occurred in 1899 when the boiler powering the lock gates exploded seventeen days after passing a safety inspection, killing dam tender Harry Weibush. While the records are incomplete, it is clear that service at Davis Island, where the river slope was steep and its flow swift, where commercial traffic was the heaviest, and where floods and ice sometimes swept without warning out of the Allegheny and Monongahela rivers, was both rigorous and risky.[25]

During the operational experiments at the Davis Island project, many design defects became apparent and were remedied when the designs for the locks and dams built farther down the Ohio were prepared. Out of the operational experiments came improved lock gate and valve designs, more efficient lock gate operating mechanisms, larger and more powerful maneuver boats, beartrap weirs for control of both drift and pool fluctuations, and various other design modifications and operational procedures which improved the capability of the lock and dam for serving traffic of the Pittsburgh harbor and also had application to the locks and dams built downstream of Davis Island on the Ohio and on other inland rivers. Operation of the project proved beyond cavil or misapprehension that it could efficiently support year-round navigation and that the construction of more locks and Chanoine dams was worthwhile.

IX

PROJECT EXTENSION

Water, water is our song.
Full nine feet for twelve months long;
On to Cairo, that's the stuff,
Nothing less will be enough.

Pittsburgh Coal Exchange, 1903

At the dedication ceremony in 1885, Colonel Merrill predicted the Davis Island Lock and Dam would last forever. It was to last only thirty-seven years before it was replaced by the Emsworth Locks and Dams, but as the canalization of the Ohio River was extended downstream the Army Engineers built fifty more locks and dams similar to that at Davis Island. By 1985, most of those fifty locks and dams had also been replaced by modern navigation structures, but two of the locks with their Chanoine wicket dams remained in service on the lower Ohio near Cairo and lockmen there still boarded maneuver boats when the river receded to prop the wickets into place as their fathers and grandfathers — in some cases literally — had before them. While the Davis Island dam did not last forever, its influence on waterway engineering technology continued for more than a century.

The extension of the six-foot canalization project down the Ohio from Davis Island began after the ice and flood of 1888 convinced the majority of the rivermen and coal shippers at Pittsburgh that the benefits of the project were greater than they had expected. At a public hearing in Pittsburgh in 1888, Colonel Merrill and a Board of Engineers heard rivermen and coal shippers unanimously support the construction of more locks and movable Chanoine dams on the Ohio. There being no expressed opposition to the project, the Board proposed that locks and dams be constructed to extend the slackwater about twenty-five miles farther downstream to the mouth of the Beaver River, thereby submerging Horsetail and Merriman's ripples, the Trap,

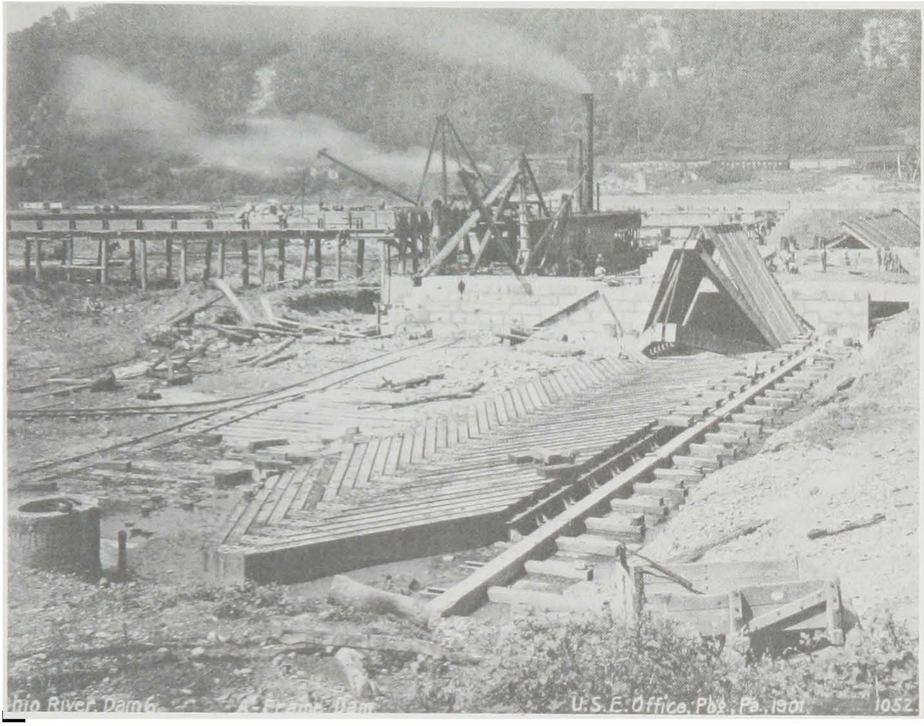
Lowrie's Ripple, and Beaver Shoals, which were some of the most hazardous obstructions to navigation on the Ohio. The twenty-five additional miles of slackwater would permit the Pittsburgh coal fleet to move that much nearer their destinations while awaiting a seven-foot stage on the river and also would alleviate the congestion which had developed on the Davis Island pool during periods of extended drought.[1]

Surveys for the sites of the new locks and dams were performed during the low-water stages of autumn in a launch drawing only fifteen inches of water; yet, the survey party had great trouble descending the river because it was merely eleven inches deep at some shoals and the channel was obstructed by teams and wagons fording the river. The surveyors chose the sites of five locks and dams below Davis Island: Dam 2 was to be located at the head of Merriman's Ripple, Dam 3 below the Trap, Dam 4 below Logstown Bar, Dam 5 at Lacock's Bar, and Dam 6 below the mouth of Beaver River. Colonel Merrill had hoped initially to canalize that river section with just four locks and dams in addition to that at Davis Island, but a fifth proved necessary a few miles downstream of the mouth of the Beaver because of a sharp bend in the Ohio and an obstructive bridge which made it difficult for tows to enter a lock built directly at the mouth of the Beaver River.[2]

Colonel Merrill chose to start the project extension with the construction of Lock and Dam 6 as the second built on the Ohio. Dam 6 would provide slackwater at the mouth of the Beaver, where the Beaver to Lake Erie Canal connected with the Ohio. Canalboats sometimes came out of the mouth of the Beaver and ascended the Ohio to Pittsburgh, and the ironmasters of Pittsburgh were interested in enlarging the canal up the Beaver to bring iron ore to Pittsburgh from the Great Lakes. Andrew Carnegie and Henry C. Frick proposed the enlargement of the canal to the Great Lakes in 1889, and Pennsylvania state government funded surveys of the route. In selecting Dam 6 as the second to be built on the Ohio, Colonel Merrill may also have recognized that its construction would practically insure funding for the remainder of the locks and dams between the Beaver River and Davis Island.[3]

When Congress in 1890 provided funds for building Lock and Dam 6, Colonel Merrill placed William Martin in charge of the construction of a stonemasonry lock and movable Chanoine dam at the site with a design and dimensions quite similar to those at Davis Island. Work had just gotten underway at Lock 6 in 1891 when Merrill died while aboard a train on a project inspection trip. In his honor, the railroad depot at Lock 6 was named Merrill Station.[4]

Lock 6 had the same 110 by 600-foot dimensions and rolling lock gates of the sort used at Davis Island, and Dam 6 had a Chanoine wicket navigable pass, but its weir sections included two beartraps,



The A-Frame wickets invented by Benjamin F. Thomas were first installed at Ohio River Dam 6. When raised, as some are in the picture, they could form a dam.

Pittsburgh District, No. 1052

each 120 feet wide, and a 120-foot section of A-Frame trestles, a new form of movable dam invented by Benjamin Thomas. Thomas, a civilian assistant engineer, was conducting extensive experiments with movable dam designs on the Big Sandy River at the border between Kentucky and West Virginia. His A-Frames represented an effort to make the trestles of service bridges serve as a dam, thereby eliminating wickets. Each metal trestle, instead of merely supporting a walkway from which Chanoine wickets were raised, in the Thomas design took the structural form of the letter "A," hence, their name: A-Frames. The upstream leg of the "A" was so wide that it touched the next when in the raised position, forming a solid surface which could serve as a dam. The A-Frame built at Dam 6 did not work well, becoming covered with sand and gravel shortly after completion, but the A-Frame system subsequently was adopted on the Cumberland River in Kentucky and Tennessee and served successfully until replaced by modern navigation structures during the 1950s.[5]

Congressional appropriations for extending the canalization project down the Ohio proved totally inadequate during the early 1890s,

and in 1896 John F. Dravo, William B. Rodgers, and other leaders of the Pittsburgh coal and shipping industry brought the House Committee on Rivers and Harbors to Pittsburgh for a personal inspection of the Ohio River project and also to promote federal acquisition of the locks and dams along the Monongahela. Boarding the steamboats *Isaac M. Mason* and *Virginia,* the Pittsburgh Coal Exchange entertained the congressmen royally on the voyage down the Monongahela and Ohio, and, partially as a result of that personal inspection by the committee of river conditions, the committee included funding for the construction of Locks and Dams 2 through 5 in the Rivers and Harbors Act of 1896.[6]

William Martin, with offices at Davis Island Lock, also was made responsible for the immediate supervision of the construction of Locks and Dams 2 through 5. Work on those four structures began in 1898, each having rolling lock gates, 110 by 600-foot lock chambers, Chanoine wickets in the navigable passes, and a combination of wicket and beartrap weirs. For reasons of economy, however, the locks were built of natural cement concrete with stone facing instead of solid stone masonry.[7]

In 1900, Major William H. Bixby, a successor of Colonel Merrill at Cincinnati in charge of Ohio River projects, advised the Chief of Engineers that Pittsburgh coal shippers wanted the minimum channel depth on the Ohio increased from six feet to nine feet. Pointing out that coal barge tows had increased both in number and in draft since the Davis Island Lock and Dam had been completed, Major Bixby recommended that project depth on the Ohio be increased to nine feet, which he contended would stand "a fairly good chance of giving all the draft that can go through the Mississippi River during the life of the present generation, and perhaps during the present century." Pittsburgh coal shippers and rivermen all along the Ohio thereon initiated a lobbying effort to secure a channel at least nine feet deep throughout the length of the Ohio from Pittsburgh to Cairo, and in 1910 their efforts were crowned with success when Congress approved the nine-foot channel depth.[8]

Major Bixby also wanted to reorganize work on the Ohio River, leaving the snagging and channel clearance work in charge of the Engineer office at Cincinnati and transferring lock and dam construction on the upper river to an Engineer office located nearer to the construction sites. The Chief of Engineers concurred and in 1901 established the Wheeling Engineer District commanded by Captain William E. Craighill and made the Pittsburgh Engineer District responsible for projects on the Allegheny and Monongahela rivers.[9]

At the time of the transfer, Captain Craighill and Major Bixby inspected the work in progress at Locks and Dams 2 through 6 and were displeased by William Martin's supervision of those projects. The

William Martin became resident engineer at Davis Island in 1884 and remained in charge there until 1905.

Pittsburgh District

quality of natural cement used in the lock walls was variable, and the two officers were disturbed by the deterioration of the natural cement concrete used in the lock walls. Craighill decided to leave Martin in charge of operations at Davis Island, but to relieve him of construction supervision; and in 1901 he asked that the Davis Island project, along with William Martin, be transferred to the Pittsburgh Engineer District.[10]

Once the transfer was made and Martin was no longer in charge of construction work, Captain Craighill laid off the men Martin had appointed to be the resident engineers at Locks 2 through 6, replacing them with resident engineers transferred from the Kanawha River project in West Virginia. The Pittsburgh Chamber of Commerce and Coal Exchange protested those transfers, alleging that Craighill had laid off the Pennsylvanians in order to replace them with West Virginians and calling for the return of supervision to the charge of William Martin at Davis Island. Senator Matthew S. Quay of Beaver, Pennsylvania, took a personal interest in the matter, telling the Chief of Engineers the men who had been laid off were his friends and neighbors, reminding the Chief that it was he who had sponsored the legislation funding the construction of Locks 2 through 6, and calling for an investigation of young Captain Craighill.[11]

Senator Quay presented the petition of protest from the Pittsburgh Chamber of Commerce to President Theodore Roosevelt, who

directed the Secretary of War to honor the request of the Chamber of Commerce if possible and return the supervision of lock and dam construction on the Ohio River to the Pittsburgh Engineer District. When the Chief of Engineers rejoined that the Pittsburgh Engineer District had never supervised construction on the Ohio, it having been done by Merrill's and Bixby's office at Cincinnati, he received in response a blunt directive from the Secretary of War: "The President directs that the Pennsylvania dams on the Ohio river be put under control of the new Pittsburg office."[12]

In accord with that order, the Chief of Engineers in 1903 transferred supervision of the construction of Locks and Dams 2 through 6, which included the structures to be built on the Ohio within the boundary of Pennsylvania, to the Pittsburgh Engineer District, then commanded by Major William L. Sibert. Major Sibert agreed with Captain Craighill, however, that William Martin should no longer direct construction on the Ohio, and he left Martin in charge only of operating the Davis Island project. When Sibert sought to reduce Martin's salary, Martin resigned in 1905 after twenty-eight years of service at Davis Island.[13]

By the turn of the century, the Davis Island Lock and Dam, like its builders, was showing the wear and tear of years of hard service, and a number of repairs and modifications were underway. After the steam boiler for lock operation exploded in 1899, a brick building adjacent to the lock house was constructed to house the new boiler and the old water tank towers were removed. When parts of the timbercrib guide walls above and below the lock, rotted by age and scarred by ice and drift, caved into the river in 1900, the guide walls were reconstructed, replacing the timbercribs with concrete. The wooden beartrap gates built in 1889 had also worn out, and in 1905 Major Sibert awarded a contract for their reconstruction to the Baker Contract Company of Pittsburgh, which rebuilt them in 1906, adding steel reinforcing to the wooden panels. While that work was in progress, Sibert also had the esplanade behind the lock filled and the boiler house and shops raised to an elevation above ordinary flooding. The highest flood of record to that date inundated the project in March 1907, however, and washed away the frame buildings.[14]

The timbercrib dam in the backchannel on the south side of Davis Island had also rotted beyond repair by the turn of the century, and, rather than reconstructing the fixed dam, Major Sibert decided to experiment with a movable dam crest that would convert the backchannel dam into an additional weir. Pittsburgh industrialists by 1902 were demanding that the Davis Island Dam be kept up in place during the winters to assure the industries along the pool an adequate water supply and fuel delivery. Whenever the dam remained up in the winter, ice floes jammed into the forebay of the lock and piled against the

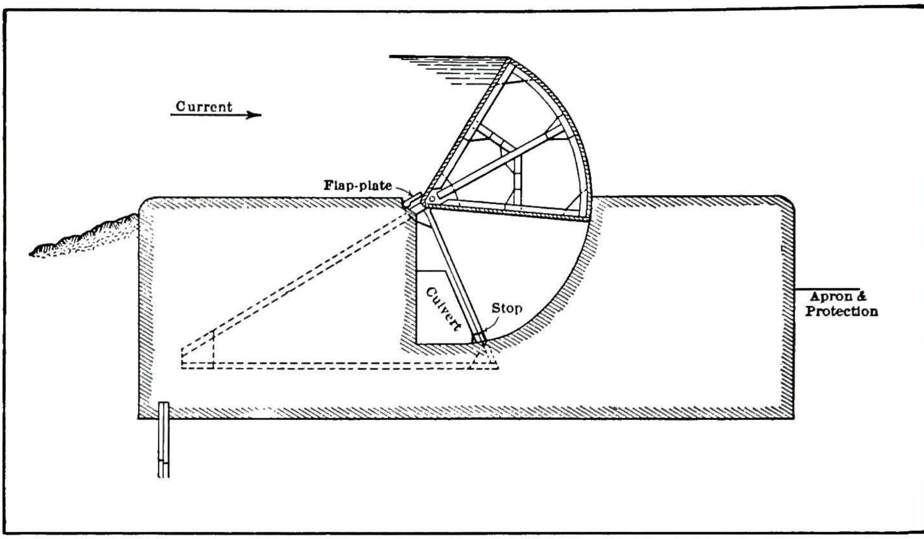
William L. Sibert, the Pittsburgh District Engineer who experimented with the Chittenden drum weir at Davis Island at the turn of the century, subsequently distinguished himself at the Panama Canal and other projects.

Pittsburgh District

Chanoine wickets, causing damages to the dam, and Sibert hoped by installing a movable weir in the backchannel to create a current that would pull the ice from the pool toward the south bank of the river away from the lock and wickets.[15]

For the experiment, Sibert reviewed the various movable dam and gate-crest types devised in the United States and Europe and selected for installation at the backchannel dam the movable dam crest invented by Hiram Chittenden, an Engineer officer who had supervised projects on the Missouri River and elsewhere. The Chittenden drum weir somewhat resembled Felix R. Brunot's caisson gate; hollow inside like an empty barrel, it could be raised or lowered by adding or subtracting water from the interior to change its buoyancy. Though models of the Chittenden drum weir worked well, there had been no full scale experiment with the device.[16]

The Dravo Contracting Company in 1904 built the new concrete dam with the Chittenden drum weirs on its crest in the backchannel of Davis Island. The fixed concrete portion of the dam had two abutments and two piers dividing the movable drum crest into three weirs, two of which were 101 feet and three inches wide and the other



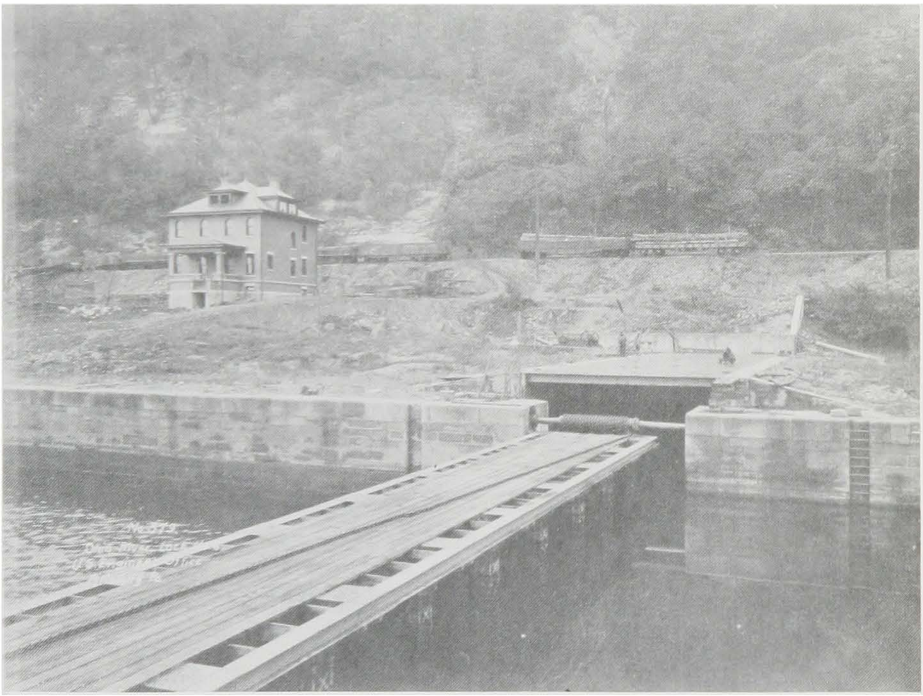
Section of a Chittenden drum wicket, which could be raised as shown to hold a pool or lowered into its recess to permit the unimpeded passage of floods and drift. Such drums were installed in 1905 in the dam blocking the left or south channel of the river behind Davis Island.

Pittsburgh District

being 202 feet and six inches wide. Atop the seven-foot high concrete section, the Chittenden drum weirs were capable of rising five feet to create a dam twelve feet high. Made of structural steel covered with wooden lagging, the drums never worked properly. During their first test in late 1904, one section of the weir stayed down while the two other sections rose. Not even hoisting with a derrick could make the laggard section rise into place as designed. Testing ended with the onset of winter flooding, and during the winter the crevices between the drums and the foundation filled with gravel and silt. It was necessary the following spring to build a cofferdam upstream of the drums to clear out the silt and gravel before raising the drums, and the drums still failed to operate properly. The experiment, in sum, failed, and similar experiments with Chittenden drum crests atop two dams on the Monongahela River also ended with signal failure; their use thereafter was abandoned.[17]

Though a new rolling lock gate made of steel with a Pratt truss and stronger undercarriage and wheels had been installed in the Davis Island Lock in 1896, the gate proved little more successful than the original wooden gate with the Howe truss. The wheels on the new gate broke so frequently that efforts to repair them ended, and both gates at the lock were dragged in and out of their recesses by main force. By 1912, the Corps of Engineers had devised steel mitering lock gates which were capable of opening and closing locks with a 110-foot width,

and those gates were used successfully at the locks built along the lower Ohio. They could not be used at Davis Island, however, unless the lock walls were rebuilt and remodeled at considerable expense. At Davis Island, therefore, new rolling lock gates were installed in 1912 which had still stronger wheels and axles, and lines through which grease could be forced down into the undercarriages without blocking off and dewatering the lock. In the new steel gates, the truss system as the main gate support member was replaced by a plate girder.[18]



This picture of the rolling lock gate at Ohio River Dam 6 shows the drum and chain used to move it in and out of its recess. In the background is the lock house and several car loads of construction materials.

Pittsburgh District

After William Martin had resigned in 1905, Major Sibert had placed Assistant Engineer John W. Arras in charge of the Ohio River project and the Davis Island project. Arras in 1914 prepared a report about the sad condition of the Davis Island Dam. While the stone-masonry lock walls and new plate girder lock gates might be serviceable for some years to come, the dam had deteriorated to the point that it required a complete reconstruction. Scour had undermined and toppled the masonry of Pier 2 in the weir, and the foundation of Weir 3 had settled to the extent that it was visibly out of line with the remainder of the dam. The wickets of the navigable pass had been raised

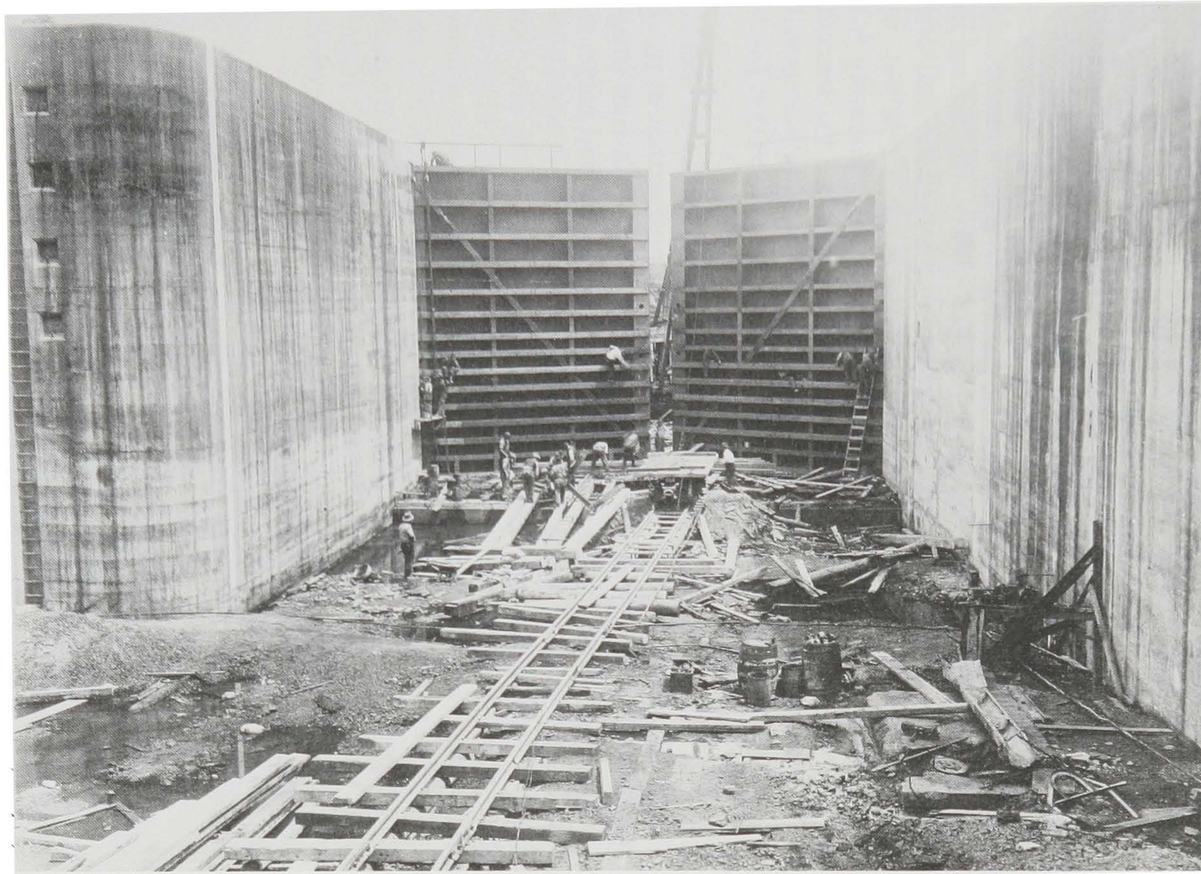
into standing position 123 times between 1885 and 1914, and it had proven difficult to keep the wicket props in the grooves atop the Pasqueau hurters. Bouncing off the metal hurters, the props had torn at the wooden grillage atop the foundation, and little of the wood remained in the vicinity of the hurters. By 1914, as often as not, the wicket props were held in place not by the notches in the hurters but by gouges in the adjacent floor of the foundation.[19]

Arras reported the dam to be beyond repair and that it would have to be entirely reconstructed, preferably with a fixed dam that could provide a more reliable depth for the Pittsburgh harbor. Pointing out that the Jones and Laughlin and Crucible Steel companies along with other industries on the Upper Ohio wanted fixed dams in order to obtain a more reliable water supply, Arras recommended the construction of a new fixed, rather than movable, dam to replace both the Davis Island project and Lock and Dam 2. Building a fixed dam downstream of Davis Island at Emsworth would not only be more economical than rebuilding the two older structures, it also would provide more reliable operations at considerably less cost.[20]

Pittsburgh coal shippers opposed the removal of the Davis Island Dam as much as they had opposed its construction, for a fixed dam at Emsworth would require that they use the lock instead of crossing the dam through a navigable pass. With the advent of the First World War in 1917, however, and the resulting increased demand for coal to fuel military armament production at Pittsburgh mills, the historic shipments of Pittsburgh coal down the Ohio to New Orleans and intermediate ports abruptly ended. Because Chanoine dams with their navigable passes were no longer used by the giant coal barge tows, the principal opposition to fixed dams on the Upper Ohio River faded, and Congress in 1917 approved the construction of a fixed dam at Emsworth.[21]

Completed in 1922 at a cost of $3 million, the Emsworth Dam was a twenty-one-foot high fixed crest concrete structure and, because it had no navigable pass for use when the lock was closed for repairs, it had two locks. One lock was the standard 110 by 600 feet of the Davis Island Lock and the other was 56 by 360 feet, the lock dimension standard on the Monongahela River. Both locks had thirteen-foot lifts and the swinging mitering type steel lock gates. Emsworth, like the dam at Davis Island, actually was two dams, one on either side of Neville Island, and thus was technically called Emsworth Dams.[22]

With the completion of the Emsworth project, the Davis Island Lock closed in August 1922. Useful government property at the lock and dam was removed and the lock reservation was sold to the owners of the adjacent railroad line. The piers, lock river wall, and projecting portions of the dam foundation which might interfere with navigation were demolished, and the stone and concrete fragments removed



Construction of the steel mitering lock gates at Emsworth Locks and Dams in 1921, which was the project that replaced Davis Island Lock and Dam. *Pittsburgh District, No. 3089*

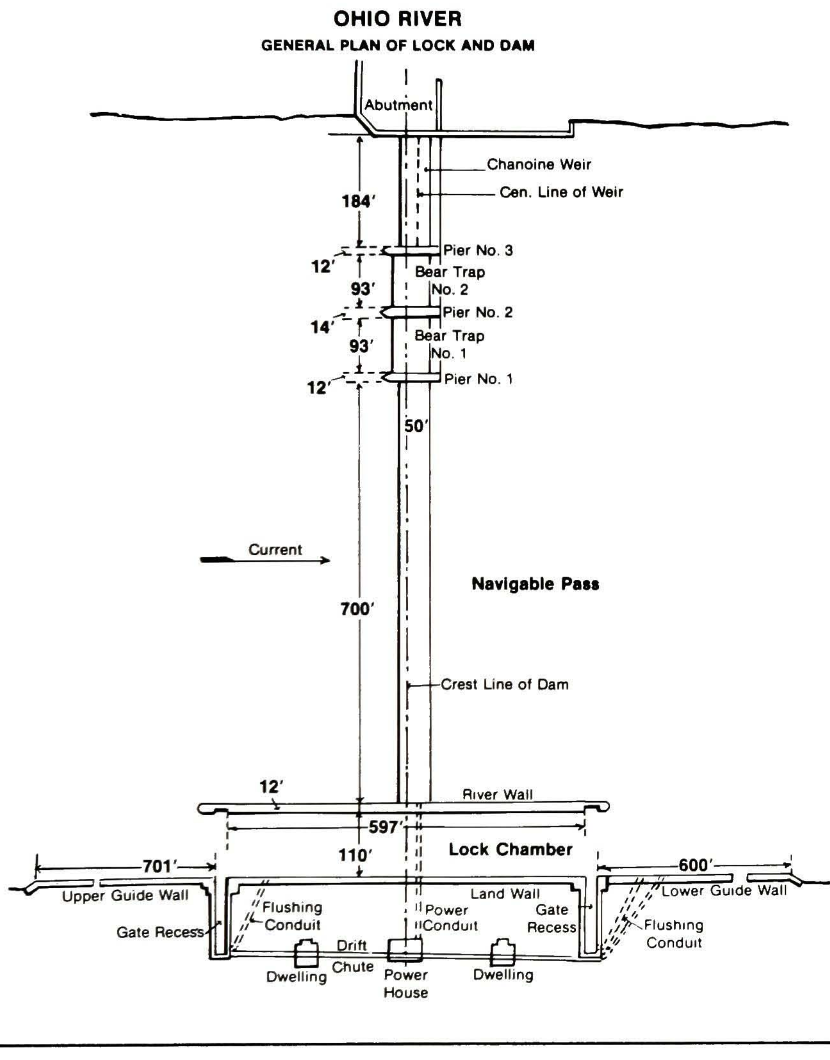
for placement on the downstream side of the Emsworth Dams to protect it against scour. The experimental Davis Island project, after thirty-seven years of operational service, thereby became part of the experimental Emsworth Locks and Dams, the first fixed dam and double lock structure on the Ohio River. The service of the Davis Island Lock and Dam thus ended before completion of the Ohio River Canalization Project, and at a time when the completion of that project was by no means assured.[23]

At the turn of the century, shippers and waterway operators awakened to the fact that a six-foot channel would not adequately meet their needs. By that date, the barges navigating the inland rivers had minimum drafts ranging from 6.5 to 8.5 feet, exceeding the capacity of a six-foot channel unless the barges ran light. With a leadership supplied by the Ohio Valley Improvement Association (organized in 1895), waterway interests initiated a campaign to secure the authorization of a minimum nine-foot channel on the river. Congress, in response, directed the Army Engineers to restudy their planning for the Ohio River, and a Board of Engineers, known as the Lockwood Board after its senior officer (Daniel Lockwood who had once served as deputy to Colonel William E. Merrill), reconsidered the Ohio River Canalization Project.[24]

The Lockwood Board reported in 1906 that canalizing the entire Ohio River to a nine-foot depth would require the construction of fifty-four locks and movable dams at a cost greater than the six-foot project by a ratio of about 6 to 5. Yet, allowing barges to load cargo to their full nine-foot draft would allow substantial savings in transport costs, or an economic advantage for the nine-foot over the six-foot project of about a three to two ratio. To achieve that savings, however, it would be necessary for traffic on the river to grow from the 9 million tons of commerce which used the river in 1906 to 13 million tons annually or more. Because the proposal to change the canalization project to a nine-foot depth was based upon a "conjectural future commerce," the Chief of Engineers did not recommend the project, preferring to leave it to the wisdom of Congress.[25]

When Congress in 1910 authorized canalizing the Ohio to a nine-foot depth and declared it intended to supply funding sufficient to complete the project to Cairo by 1922, the Corps of Engineers employed a large construction force and began building the locks and movable dams in a general downstream order. By designing Chanoine wickets up to twenty-four feet long, thereby allowing an increased lock lift at each dam, and by relocating some of the locks and dams, the Corps eliminated three (Nos. 40, 42, and 54) locks and dams, reducing the number constructed to fifty-one and lowering project construction costs. Congress did not supply funding at the rate promised in 1910, however, and the job was only half completed in 1917 when

tonnages moving on the river plummeted. The historic shipments of Pittsburgh coal to the South suddenly ceased in 1917, cutting river traffic by half and leaving only 4.5 million tons of commerce on the river that year. According to Thomas P. Roberts, the Ohio abruptly became merely a "playground for owners of small locally owned boats."[26]



Plan of a "typical" Ohio River lock and dam of the type built on the river between 1900 and 1929. They had two beartrap weirs, a Chanoine weir section, and a navigable pass. This plan shows the recesses for the rolling lock gates, but about 1914 the Engineers designed steel mitering lock gates which were substituted for rolling gates thereafter.

Pittsburgh District

The question then arose whether it would be a wise investment of federal funds to continue building the nine-foot project in the face of a commerce apparently dwindling to nothing. At that juncture, the Chamber of Commerce and industrial interests of the Pittsburgh area, as they had during the Davis Island political controversy of the 1870s, united behind the Ohio River Canalization Project. Not only did they unite to lobby for full project funding, they also initiated the shipment of steel and fabricated metal products down the Ohio aboard what were called the "Million Dollar Tows." With added support from the downriver communities, in 1922 they won full funding for the project, allowing the Engineers to rush construction on the lower river and open the nine-foot channel from Pittsburgh to Cairo in 1929. By the time the project was completed, traffic on the river had climbed to 22 million tons annually, substantially surpassing the 13 million tons projected in the nine-foot economic justifications.[27]

Except for temporary setbacks during national economic depressions and recessions, commercial traffic on the Ohio steadily increased after 1929. By 1985 the traffic moving on the river had multiplied nearly twenty-fold over the nine million tons that had traveled it in 1906. Until 1929, most traffic on the Ohio had been downbound, moving with the current to Southern ports, but the slackwater pools held by the Chanoine wicket dams made upstream navigation nearly as convenient as downstream, and by the 1950s upbound traffic matched downbound in volume. During the 1950s, the Corps of Engineers began modernizing the river, essentially converting it from a two-lane to a four-lane highway for navigation through the construction of high-lift locks and dams, each generally replacing two or more of the low-lift locks and wicket dams. Only two of the Chanoine wicket dams, Dams 52 and 53 nearest Cairo, remained in service in 1985.[28]

A major factor in the growth of waterborne commerce on the river was the industrial development which took place on its banks, taking advantage of the availability of low-cost waterway transport and abundant water supply for condenser cooling and manufacturing purposes. Starting with industrial plants at Ambridge, Aliquippa, and other points on the Upper Ohio near Pittsburgh, riverside industrial development followed the slackwater project downriver. While the influence of the slackwater project on regional industrial development cannot be separated from other elements of the region's economic structure, it seems apparent that steel plants, chemical factories, petroleum refineries, and similar primary industries chose riverside locations because the slackwater project made year-round barge transport and water supply available. Those industries and a growing population created a market for electric power, resulting in the construction of steam-electric power plants along the river where they could secure barged coal as fuel. Secondary industries which converted

primary materials into manufactured products then selected sites on the banks of the river where basic materials and power were easily accessible. As the process, started at Pittsburgh with the Davis Island Lock and Dam, proceeded downriver following the slackwater project, the point of heaviest traffic density on the Ohio also shifted downstream, moving from the Pittsburgh area during the 1950s to the Huntington and Cincinnati area and on downstream to Louisville and below during the 1970s.[29]

By 1985 the entire Ohio River served as a collective super-plant facility. Industry all along its 981-mile length used the river for the delivery and exchange of fuels, raw materials, and manufactured products in various processing stages. Electric power produced on its banks served people and industries located considerable distances from the river, and the products manufactured at the riverside plants had national and international markets. In sum, through the pioneer Davis Island Lock and Dam project, General Moorhead, Colonel Merrill, and their colleagues had much greater impact upon regional and national life than ever they could have imagined.

X

PROJECT INFLUENCES

The dam as now constructed has converted what was at times for months almost a dry river bed into a navigable pool, or basin, furnished abundant water for any or all the vessels navigating the upper reaches of the Ohio. It has thus rendered it possible to transport freight in and around Pittburgh at very much less cost than when hauled overland; it has greatly reduced the risks to the coal and other interests doing business in this section of the country, and in this way has stimulated the industries of this important manufacturing centre, in consequence of which the revenues of the government are daily increasing.

Lewis M. Haupt, 1886

The Davis Island Lock and Dam created the Pittsburgh harbor; of that much we are certain. How much the project and the harbor it created influenced and stimulated the industrial development of Pittsburgh is uncertain; no effort ever was made to analyze its influences, or benefits, statistically, though we do have the analysis quoted above by Lewis Haupt, a civil engineer of Philadelphia who provided his analysis while under oath in the case of *Alfred Pasqueau* v. *the United States.* Haupt spoke only of the project's benefits to navigation and the reduced cost of transportation thereby resulting. He might also have mentioned the improved water supply the project made available to Pittsburgh's industry, the uses made of the pool for recreation, and its contributions to pollution abatement and national defense.[1]

While the Davis Island project was built to improve navigation in the Pittsburgh harbor and on the Ohio, it also had unquantified but substantial benefits for other purposes. Where municipal and industrial effluents and refuse had once lain stinking in the sun on

the banks of the nearly dry river beds during late summer and autumn, after 1885 the effluents were submerged by the Davis Island pool. The extent to which this project feature benefited public health cannot be determined, but in at least one instance the dam was raised at the request of city authorities so the pool would cover those effluents and help avert a public health menace. The project's major contribution to national defense came during the First World War when it was considered vital to military production and was guarded against sabotage. The dam was kept up during the winters of 1917-1918 in order that materials might keep moving by river to the Pittsburgh plants producing armaments for the American and Allied armies. It was the industrialists of Pittsburgh who had demanded the construction of the project, and it was the industrialists again in 1917, not the rivermen, who urged that it be replaced by a fixed dam at Emsworth. It therefore appears that the benefits of the project were more widespread than for the improvement of navigation alone.[2]

The people of Pittsburgh took great civic pride in the Davis Island project and the engineering achievement it represented. They displayed models of the project at the annual civic fair held in the city during the late 19th century; Pittsburgh photographers made and sold views of the lock and dam to the public; and civic boosters invariably mentioned the project as one of the features of interest among the many attractions of the Pittsburgh area.[3]

The Corps of Engineers took equal pride in the project. When delegations of engineers from other nations visited the United States to study American engineering, they were routed by Corps officers through Pittsburgh for a tour of Davis Island. The Chief of Engineers printed project maps and diagrams in 1891 for public information and display along with models of the lock and dam at the Chicago Columbian Exposition and at other world fairs. When the Pittsburgh Chamber of Commerce in 1904 asked the Chief for the loan of the Davis Island project model to become part of the city's exhibit at the St. Louis World's Fair, they were advised it could not be loaned because it would be part of the Corps' exhibit in St. Louis.[4]

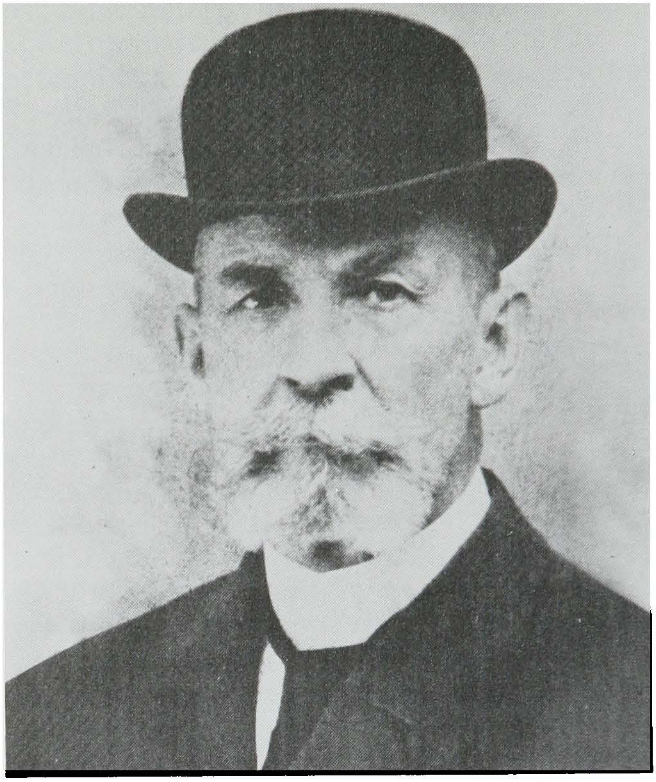
The international exchange of technology initiated in 1874 by Colonel Merrill continued after the project was complete in 1885. A French engineer attended the 1885 dedication ceremony, and in 1888 the chief of the French Corps des Ponts et Chaussées visited Davis Island for a personal inspection of the project. American Engineer officers stationed in Europe furnished copies of the plans and information about the Davis Island project to European engineers. Records do not indicate the extent to which the Davis Island project, or American waterway engineering technology in general, may have influenced European waterway engineering, but no doubt the French engineers who continued building movable dams on the order of the

Davis Island project found the design and construction accomplishments at Davis Island useful in preparing their own designs.[5]

One unfortunate incident marred the international technological exchange. As recommended by Colonel Merrill, Alfred Pasqueau of the French corps delayed filing suit for use of his patented hurter at Davis Island and on the Kanawha River until 1886, asking for a payment of $100 royalty for each hurter used, or a total of $53,900. Shocked by the size of Pasqueau's claim, Colonel Merrill recommended that he be paid no more than $5 per hurter, or a total of less than $3,000, and he submitted to the Chief of Engineers copies of all his correspondence with Pasqueau in order that his connection with the case might be made clear. As often happens in the adversarial atmosphere of the court system, the dispute became acrimonious as time passed. Merrill and other American engineers thought it unseemly that Pasqueau had given his invention to the government of France without compensation other than the Legion of Honor medal and then demanded such exorbitant payment from the American government, and that became the argument of the attorneys for the United States: that Pasqueau, by giving his invention to the French government, had surrendered to the public all of his rights in the invention.[6]

The Pasqueau case dragged through the court system for years at an immense cost to both the claimant and the defendant. Using Merrill's correspondence as evidence, Pasqueau's attorneys in 1891 won a $26,000 judgment for the client as compensation for Merrill's use of hurters at the Davis Island Dam. At the dams on the Kanawha River, however, when it had become evident that Pasqueau would sue, the engineers had substituted hurters of a different design invented by Benjamin Thomas and Addison Scott, two civilian employees of the Corps of Engineers, and the attorneys for the government contended those hurters did not infringe upon Pasqueau's patent. After fourteen years of litigation, the U.S. Court of Claims in 1900 awarded Pasqueau an additional $2,214 for the use of his hurter on the Kanawha. Attorneys' fees by that date probably had consumed most of the royalty awarded to Pasqueau in the cases, and the engineer in charge of the Kanawha River thought the decision of the court "not very far from a victory for the U.S. after all."[7]

The Pasqueau litigation did not, however, deter a continuing exchange of technological information between American and European engineers. Captain Frederick A. Mahan, after leaving Davis Island in 1884, spent much of the remainder of his Army career in Europe. When he retired in 1900, he revised his father's standard engineering textbook used at West Point and elsewhere, adding a lengthy discourse on movable dam technology at Davis Island and in Europe. When President Theodore Roosevelt in 1903 created the Inland Waterways Commission to plan the revitalization of American inland river com-



Frederick A. Mahan retired from the Corps in 1900 and lived the remainder of his life in Paris while advising American engineers of advances in European waterway technology. *Pittsburgh District*

merce and other water resource developments, Mahan guided the Commission on a tour of European waterway projects and was appointed as U.S. Agent in Europe for the continuing study of international waterway engineering technology. Mahan also served as consulting engineer for the National Waterways Commission of 1911 and published widely the results of his investigations of European technology. At the American entry into the First World War, he was recalled to active service, becoming a military attaché in Paris where he died in 1918.[8]

While the influence of the Davis Island project upon European waterway engineering is uncertain, its influence upon American waterway design is clear. By 1929, the Corps of Engineers had completed fifty additional locks and dams on the Ohio River, all based upon the design and operational experiments at Davis Island. The Ohio River canalization project proved to be such a success that as the original structures deteriorated all save two were replaced with modernized structures.[9]

The 110 by 600-foot lock chamber dimensions established by Colonel Merrill at Davis Island in 1878 became the standard, not only at Ohio River locks but also on other inland rivers. When Congress approved the canalization of the Upper Mississippi River in 1930, it specified that the locks on the Mississippi would have dimensions not less than the 110 by 600-foot chambers built on the Ohio, and all save one of the twenty-six locks built on the Upper Mississippi between 1930 and 1940 were 110 by 600 feet within their chambers. Those dimensions, in fact, became the standard on American inland rivers and were used where possible on tributaries of the Ohio and Mississippi, though the narrow channel width of tributaries and other local conditions often prevented the use of such large locks. As a result, marine engineers and operators designed their barges and tows to fit into the 110 by 600-foot lock chambers, and when the Corps of Engineers during the late 20th century modernized the Ohio River project, extending the length of lock chambers to accommodate larger barge tows, it retained the 110-foot chamber width in the new locks.[10]

Those were perhaps the most direct and obvious influences of the Davis Island project, but there also were less obvious influences, notably in the impetus it gave to American studies of European waterway technology and further experimentation with movable dam systems. Godfrey Weitzel, who had served with Merrill on the 1874 Board responsible for the movable dam studies, applied several of the European movable dam systems to the projects he was directing at the Louisville and Portland Canal and the Sault Ste. Marie Canal. He installed a Pasqueau hurter and Chanoine dam combination in the Sault Ste. Marie Canal in 1881 for use as an emergency cofferdam, and he built Boule and Thenard movable dams at the Louisville and Portland Canal in 1883. At Louisville, where boat traffic sometimes descended the Falls of the Ohio at higher water stages to bypass the canal, the Boule and Thenard movable dams served to divert water from the river into the canal during periods of low flow, and they were lowered at higher river stages to allow boat traffic to pass down over the Falls.[11]

Alerted to the potentials of movable dam systems, American engineers experimented widely with various movable dam designs. As previously mentioned, Benjamin F. Thomas, who conducted extensive experiments with Poirée needle dams on the Big Sandy River, invented the A-Frame trestle dam used at Ohio River Dam 6 and on the Cumberland River during the 1930s. Guy B. Bebout, an engineer in the Wheeling Engineer District, invented a modified Chanoine wicket system which became known as Bebout wickets in 1908 and patented his device. His models so impressed the Chief of Engineers that in 1915 the Corps installed Bebout wickets at Ohio River Dam 13. Bebout wickets resembled Chanoine wickets but had a hinging arrangement

which allowed them to fall automatically when pressure was exerted at their tops; that is, river rises could cause them to fall to their foundation automatically. Bebout received a royalty for their use and hoped they would replace the Chanoine system, but his hope went unrealized because his wickets sometimes collapsed at inopportune moments after being struck by drift or wave surges from passing boats.[12]

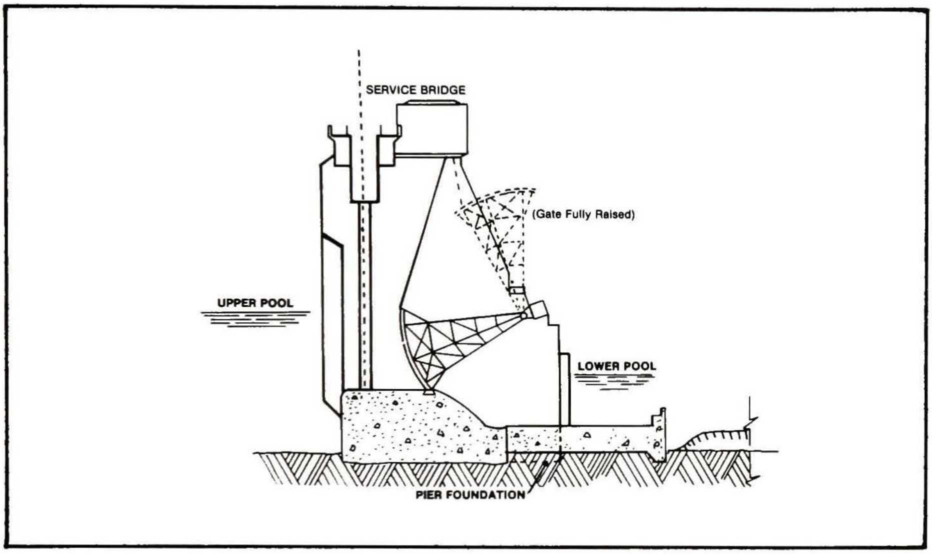
A similar problem developed with the Betwa wickets installed by the Pittsburgh Engineer District on two Monongahela River dams in 1905. After the failure of the Chittenden drum weir on the backchannel dam at Davis Island, Major William L. Sibert had selected for further movable dam experimentation the wickets developed by British engineers and used on the Betwa Dam in India. Designed by the British engineers as automatic spillway closures for dams, the Betwa wickets did not work satisfactorily on the Monongahela River because heavy boat and barge traffic constantly tripped the automatic Betwa wickets at untoward moments.[13]

David A. Watt, a Corps employee who co-authored with Benjamin Thomas a standard textbook on dam construction, conducted further experimentation with movable dam systems when hired by the State of New York in 1905 to plan a project for the enlargement of the Erie Canal. On the recommendation of Major Sibert at Pittsburgh, Watt toured Europe to study movable dam technology there. For the canalized section of the Mohawk River from Rome, New York, east to the Hudson River, Watt adopted the bridge-type movable dam used on the Moldau River in Bohemia and also at points on the Seine. The system involved the construction of bridge piers spanned with ordinary bridge trusses and with metal Boule gate frameworks suspended under the bridge spans. The Boule gates could be hoisted up to the bottom of the bridge spans opening a clear channel for ice and flooding, then lowered into place to hold a pool during periods of low river flow. Watt designed eight of the bridge dams which were built on the Mohawk River by 1910.[14]

Colonel Merrill's studies of and experiments with the American beartrap gate weirs also stimulated renewed interest in various uses for that water control appliance. Colonel William A. Jones, the Engineer officer stationed at St. Paul, Minnesota, invented a modified beartrap gate system for use as automatic weirs in the outlets of the reservoirs constructed by the Corps in the headwaters of the Mississippi River during the late 19th century. Horace Harding, a civilian engineer working in the Engineer office at Mobile, Alabama, devised another beartrap system for use as an automatic weir in the Muscle Shoals Canal and elsewhere during the 1880s. And a remarkably inventive Wisconsin lumberman, Theodore Parker, in 1887 invented a beartrap gate with three instead of two leaves, the third leaf providing upstream protection against gravel and drift interfering with gate operations.

The Corps of Engineers installed one of Parker's beartraps in Ohio River Dam 13 as an experiment, but it did not prove sufficiently successful to warrant a wider application.[15]

Theodore Parker also invented the segmental arc gates, now known as Tainter gates, widely used by the Corps of Engineers on the Ohio and other rivers for a more positive control of water flow.

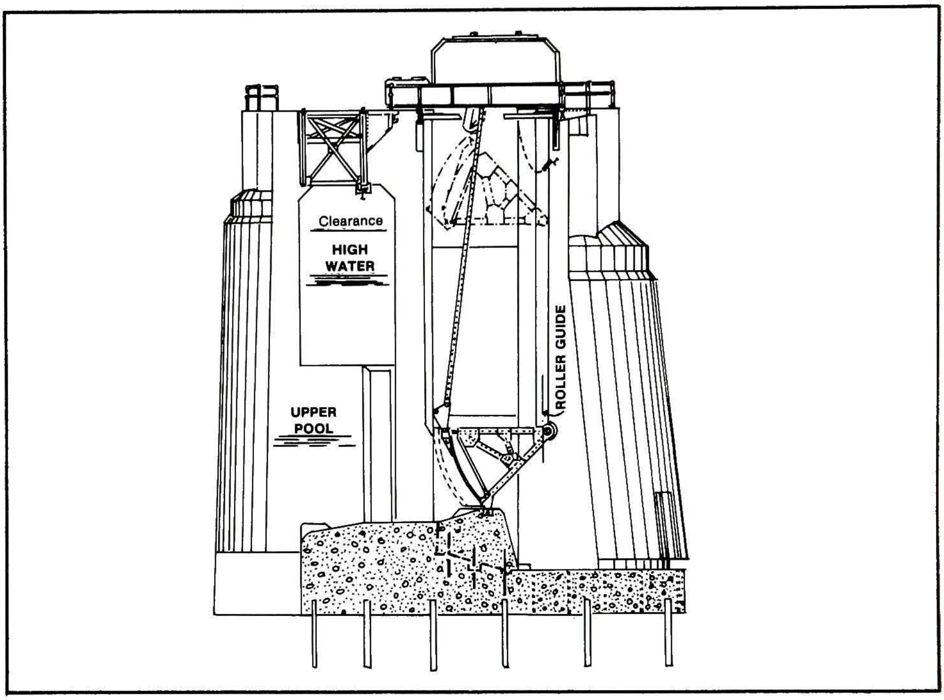


Section of a Tainter gate of the type used at modern Ohio River dams, showing how the gate rested against its foundation sill to hold a slackwater pool and can be rotated up out of the way of floods. *Pittsburgh District*

Parker sold his rights in the invention to Jeremiah B. Tainter, who patented the gate system in 1886 and for many years collected a royalty of $75 a gate for their use. Tainter gates consisted of a panel curved in the arc of a cylinder and supported by arms connected to trunnions anchored in piers at both sides of the gate. When down against the sill of a dam foundation, they held an upstream pool, and when floods or drift arrived they could be rotated up out of the river to open the channel or rotated down under the river surface to provide an unimpeded passageway for ice. Major William L. Marshall during the 1890s became the first Engineer officer to use the Tainter gates, adopting them for use on the Fox River in Wisconsin and the Illinois and Mississippi Canal.[16]

Although American waterway engineers during the 1930s abandoned movable dams of the Chanoine type for use on navigable rivers, because they limited the amount of lift provided at each dam to the length of the wickets, experimentation with various types of movable dam crests for the control of pool elevations continued. American

engineers during the 1930s again borrowed European technology through use of the roller dams patented by the Krupp Corporation of Germany. Consisting of hollow drums rolling up and down between piers to hold or release pools, the Krupp roller dams were built on the Kanawha River, at Gallipolis Dam on the Ohio, and at dams on the Upper Mississippi River. The Pittsburgh Engineer District during the 1930s continued its national leadership in movable dam design by experimentation with a lifting bulkhead gate invented by William E. Sidney, the District's chief mechanical engineer, and it installed such



Section of a modified Tainter gate invented by William Sidney of the Pittsburgh Engineer District. Rather than rotating upwards, it was raised to the top of the overhead bridge to provide more clearance for the passage of flooding and ice.

Pittsburgh District

a gate in the Emsworth backchannel dam in 1938. Though the Army Engineers of Pittsburgh long maintained that the Sidney gate was superior, the Tainter gate with its fewer movable parts eventually became the standard movable dam crest, both at the modern navigation structures on the Ohio River and for spillway control at reservoirs on the tributaries.[17]

As an experiment, the Davis Island project was eminently successful, not only in creating a harbor for Pittsburgh but also in stimulating an international exchange of technology and in directing

the attention of American waterway engineers to the potential applications of movable dam and movable crest gate designs. When Colonel Merrill began his studies of international engineering in 1874, Americans were still building stone-filled timbercrib dams of a type known to the Ancient Romans. By the time he completed the Davis Island Dam, experimentation with dam design had blossomed in America, producing many of the complex structural features seen at the dams on the inland waterways of the 20th century. A century after the Davis Island Dam was completed, that innovative approach to waterway engineering technology had not faded.

What might have happened if the experiment at Davis Island had failed? What if, as rivermen then predicted, the Chanoine dam system had not worked on the Ohio as planned and Colonel Merrill had blasted it from the channel? Too many variables exist for a predictive scenario, yet it seems probable that no more dams would have been constructed on the Ohio River and its channel would have remained nearly dry during several months of each year. When the shipment of Pittsburgh coal downriver to New Orleans ended in 1916, it probably would have, as it almost did, sounded the death knell for the inland river towboat and barge industry. Pittsburgh today would have no harbor serving as a collective super-plant facility for the industries located around its perimeter, nor would it have regattas and other waterfront recreation, and visits to Point State Park on hot summer afternoons might not be a pleasant experience. Though the Davis Island Lock and Dam did not, as its builder predicted in 1885, last forever in the physical sense, the project was recognized at its centennial in 1985 as a landmark in the annals of international waterway engineering technology.

NOTES

I: RIPPLES ON THE OHIO

1. James Hall, *Letters from the West* (London: Henry Colburn, 1828), pp. 196-97; Timothy Flint, *Recollections of the Last Ten Years Passed in Occasional Residences and Journeyings in the Valley of the Mississippi* (New York: Da Capo Press, 1968 reprint of 1826 edition), pp. 19-20. Lt. Gen. Raymond A. Wheeler's remarks concerning the Pittsburgh harbor in 1946, quoted in the Introduction, are from Commonwealth of Pennsylvania, *Port of Pittsburgh Survey: First Phase* (Pittsburgh: Port of Pittsburgh Survey Committee, 1947), p. 21.

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3. Johnson, *The Headwaters District,* pp. 52-54; James W. Fawcett, "Magnus Murray," *Western Pennsylvania Historical Magazine* 50 (October 1967):273-80.

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27. Bogart, "William Milnor Roberts, Past-President, ASCE," pp. 531-37; "Death of Colonel T.P. Roberts, Noted Engineer," *Pittsburgh First* 5 (March 1924):2.

II: RADICAL PLANNING STUDIES

1. Margaret Merrill, "William E. Merrill," *Professional Memoirs, Corps of Engineers* 9 (November 1917):639-42; William E. Merrill, ACP File 1113ACP73, Records of the Adjutant General's Office, Record Group 94, National Archives, Washington, DC; William E. Merrill, *Iron Truss Bridges for Railroads. Methods of Calculating Strains, with Comparison of the Most Prominent Truss Bridges, and New Formulas for Bridge Computations; Also the Economical Angles for Struts and Ties* (New York: D. Van Nostrand, 1870), passim.

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9. Jones and Laughlin, Oliver and Phillips, Moorhead Adams & Co. et al., to Maj. William E. Merrill, 17 Oct. 1871, File 202, Letters Received, 1871-1886, NARG 77.

10. William H. Brown, John O'Neil, Samuel Cable et al., to Maj. William E. Merrill, 20 Nov. 1871, in ibid.

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Corps of Engineers 10 (September 1918):747-50; Godfrey Weitzel, *Lock-Gates. Translation of Notes Accompanying Drawings Concerning Construction of Iron Lock-Gates for Harbor of Weser River, Germany* (Washington, DC: Engineer Department General Publication, 1873), passim; Der Standesamt Winzeln auf American Embassy, Bonn, 30 Jan. 1962, in Godfrey Weitzel papers, Cincinnati Historical Society, Cincinnati, OH; Johnson, *The Falls City Engineers*, pp. 122-28.

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III: INTERNATIONAL PLANNING STUDIES

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2. William Windom to Brig. Gen. A.A. Humphreys, 25 Aug. 1873, File 1888, Ltrs. Rec., 1871-1886, NARG 77; Brig. Gen. A.A.

Humphreys to William Windom, 30 Aug. 1873, Letters Sent, 1871-1886, NARG 77.

3. U.S., *Congressional Record,* 43d Cong., 1st sess., 1873-74, p. 62; Schonberger, *Transportation to the Seaboard,* pp. 27-32; Johnson, *The Headwaters District,* pp. 134-36; Johnson, *Men, Mountains and Rivers,* pp. 82.

4. U.S. Army, Corps of Engineers, *Annual Report, 1874,* pp. 527-44; U.S. Army, Corps of Engineers, *Annual Report, 1879* (Washington, DC: Government Printing Office, 1880), pp. 1390-98; U.S., Congress, House, *James River and Kanawha Canal,* H. Exec. Doc. 219, 43d Cong., 1st sess., 1874, passim.

5. U.S., Congress, House, *James River and Kanawha Canal,* H. Exec. Doc. 219, 43d Cong., 1st sess., 1874, passim; U.S., Senate, Select Committee, *Report of the Select Committee on Transportation - Routes to the Seaboard,* S. Report 307, 43d Cong., 1st sess., 1874, II, 528; U.S. Army, Corps of Engineers, *Annual Report, 1874,* p. 499.

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IV: PROJECT POLITICAL CONFLICT

1. Horatio G. Wright is quoted in U.S. Army, Corps of Engineers, *Annual Report, 1877,* p. 656; James K. Moorhead to Maj. Gen. A.A. Humphreys, 16 Jan. 1874, File 88, Ltrs. Rec., 1871-1886, NARG 77; James S. Negley to Maj. Gen. A.A. Humphreys, 10 Feb. 1874, File 206, Ltrs. Rec., 1871-1886, NARG 77; Cowan, *Memorial Volume: James Kennedy Moorhead,* pp. 51-52.

2. Cowan, *Memorial Volume: James Kennedy Moorhead,* pp. 51-52, prints Ricketson's account of the Committee meeting.

3. Ibid.; Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 29 March 1875, File 874, Ltrs. Rec., 1871-1886, NARG 77.

4. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 2 June 1874, Ltrs. Rec., 1871-1886, NARG 77; Dennis H. Mahan and Frederick A. Mahan, *A Treatise on Civil Engineering* (New York: John Wiley & Sons, 1902), is Frederick Mahan's revised edition of his father's text.

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11. U.S. Army, Corps of Engineers, *Annual Report, 1875,* pp. 686-87.

12. *Pittsburgh Gazette,* 11 Dec. 1875; U.S. Army, Corps of Engineers, *Annual Report, 1877* (Washington, DC: Government Printing Office, 1878), pp. 645-54.

13. U.S. Army, Corps of Engineers, *Annual Report, 1877,* pp. 645-54; *Memorial Relative to the Ohio River Navigation from the Pittsburgh Coal Exchange and the Steamboatmen's Association* (Pittsburgh: Mills and Bros., 1876), passim.

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19. George P. Miller to Maj. Gen. A.A. Humphreys, 3 Feb. 1877, File 313, Ltrs. Rec., 1871-1886, NARG 77.

20. Maj. John G. Parke to Col. Zealous B. Tower, 14 Feb. 1877, File 313, in ibid.; U.S. Army, Corps of Engineers, *Annual Report, 1877,* pp. 637-56.

21. James K. Moorhead to Maj. William E. Merrill, 4 May 1876, File 886, Ltrs. Rec., 1871-1886, NARG 77; Maj. William E. Merrill

to Maj. Gen. A.A. Humphreys, 12 March 1877, File 403, in ibid.; *Pittsburgh Commercial,* 13 Feb. 1877; editorial in *Engineering News* 4 (8 December 1877):345; Moorhead, *Whirling Spindle,* pp. 205-06; "Iron Pioneer: Henry W. Oliver," *Greater Pittsburgh* 23 (September 1942):4-5.

22. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 16 May 1877, File 528, Ltrs. Rec., 1871-1886, NARG 77; Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 13 Oct. 1876, File ~~1752~~, in ibid.; Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 29 Sept. 1877, File 528, in ibid.; Lt. Frederick A. Mahan to Maj. Gen. A.A. Humphreys, 15 June 1878, File 1069, in ibid.; U.S. Army, Corps of Engineers, *Annual Report, 1878* (Washington, DC: Government Printing Office, 1879), p. 802.

V: LOCK CONSTRUCTION COMMENCES

1. Lt. Col. Horatio G. Wright to Maj. Gen. A.A. Humphreys, 25 Jan. 1878, File 750, General Correspondence, 1894-1923, Office of the Chief of Engineers, NARG 77.

2. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 29 Dec. 1877, File 2466, Ltrs. Rec., 1871-1886, NARG 77.

3. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 2 Apr. 1877, File 532, in ibid.; Maj. John G. Parke to Maj. William E. Merrill, 30 June 1877, Ltrs. Sent, 1871-1886, NARG 77.

4. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 2 Apr. and 27 Oct. 1877, Files 532 and 2144, Ltrs. Rec., 1871-1886, NARG 77; Maj. John G. Parke to Maj. William E. Merrill, 30 June 1877, Ltrs. Sent, 1871-1886, NARG 77; Acting Secretary of State F.W. Seward to Secretary of War George McCrary, 26 Apr. 1877, File 532, Ltrs. Rec., 1871-1886, NARG 77. The encyclopedia used by Merrill was Edward Spon, *Spon's Dictionary of Engineering, Civil, Mechanical, Military, and Naval* (8 vols.; London: E. & F.N. Spon, 1874).

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6. U.S. Army, Corps of Engineers, *Annual Report, 1877,* pp. 802-05.

7. Ibid.

8. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 15 July 1878, File 1162, Ltrs. Rec., 1871-1886, NARG 77; Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 18 Sept. 1878, File 2247, in ibid.

9. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 15 July 1878, File 1162, Ltrs. Rec., 1871-1886, NARG 77; Johnson, *The Falls City Engineers,* pp. 64-65. Invented in England in 1824 by Joseph Aspdin, Portland cement was not produced in the United States until 1872 and then on a small scale. The first concrete highway pavement, bridge span, and canal locks in the United States all were constructed in 1892-93. Maj. William L. Marshall built the first concrete canal locks on the Illinois and Mississippi Canal in 1892, and the Louisville Engineer District built the first concrete river lock in 1895 on the Rough River, Kentucky. See "Who Invented Portland Cement?" *Engineering News* 65 (27 April 1911):515, and William M. Black, "Advances in Waterways Engineering during a Half Century," *Transactions of the American Society of Civil Engineers* 93 (1929):206.

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12. Ibid.; Maj. John G. Parke to Maj. William E. Merrill, 25 July 1878, Ltrs. Sent, 1871-1886, NARG 77.

13. P.C. Bullard, "John Grubb Parke," *Professional Memoirs, Corps of Engineers* 10 (March 1918):192-95; editorial in *American Engineer* 9 (24 April 1885):195.

14. Maj. William E. Merrill to Maj. John G. Parke, 10 Aug. 1878, File 1801, Ltrs. Rec., 1871-1886, NARG 77; Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 30 Aug. 1878, File 1801, in ibid.; Maj. John G. Parke to Maj. William E. Merrill, 4 Oct. 1878, Ltrs. Sent, 1871-1886, NARG 77.

15. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 24 July 1878, File 1572, Ltrs. Rec., 1871-1886, NARG 77; Lt. Frederick A. Mahan to Maj. William E. Merrill, 20 May 1879, File 1395, in ibid.; George R. Harlow, "James Haywood Harlow, M. ASCE," *Transactions of the American Society of Civil Engineers* 83 (1919-1920):2200-04.

16. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 19 Aug. 1878, File 1904, Ltrs. Rec., 1871-1886, NARG 77; Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 20 Aug. 1878, File 1915, in ibid.; *Pittsburgh Commercial Gazette,* 7 Oct. 1885.

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18. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 23 Jan. 1879, File 212, Ltrs. Rec., 1871-1886, NARG 77; U.S. Army, Corps of Engineers, *Annual Report, 1879,* pp. 1299-1305.

19. *Pittsburgh Commercial Gazette,* 26 Feb. 1879; James A. Henderson, "Dean of Rivermen Reminisces," *Greater Pittsburgh* 17 (November 1936):18-19; James A. Henderson, "Reminiscences of the Rivers," *Western Pennsylvania Historical Magazine* 12 (October 1929):235-36.

20. *Pittsburgh Commercial Gazette,* 23 Dec. 1878.

21. James K. Moorhead to Maj. Gen. A.A. Humphreys, 13 Jan. 1879, File 118, Ltrs. Rec., 1871-1886, NARG 77; Maj. John G. Parke to Carnegie Brothers & Co., Spang, Chalfant & Co., Wilson Walker & Co. et al., 13 June 1877, Ltrs. Sent, 1871-1886, NARG 77; *Pittsburgh Commercial Gazette,* 25 Feb. 1879; U.S., Congress, *Congressional Record,* 45th Cong., 3rd sess., 1879, Vol. 8, Pt. 1, pp. 421, 516, and 736; Maj. John G. Parke to Maj. William E. Merrill, 1 Feb. 1879, Ltrs. Sent, 1871-1886, NARG 77; Maj. Gen. Horatio G. Wright to Chairman, Senate Committee on Commerce, 19 Feb. 1879, in ibid.; "The Ohio River Improvement Commission in Washington," *Engineering News* 6 (27 December 1879):417-18.

22. Editorial in *American Engineer* 1 (January 1880):6; James K. Moorhead to Maj. Gen. Horatio G. Wright, 30 Oct. 1879, File 4008, Ltrs. Rec., 1871-1886, NARG 77; John W. Jordan, *Encyclopedia of Pennsylvania Biography* (New York: Lewis Historical Publishing Co., 1914), pp. 74-75; Johnson, *The Headwaters District,* pp. 141-42.

23. Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 28 Nov. 1879, File 5121, Ltrs. Rec., 1871-1886, NARG 77.

VI: CONSTRUCTION OF THE LOCK AND PASS

1. Maj. William E. Merrill to Maj. Gen. A.A. Humphreys, 7 Apr. 1879, File 906, Ltrs. Rec., 1871-1886, NARG 77; editorial note in *Engineering News* 7 (27 March 1880):111; Johnson, *Men, Mountains and Rivers,* pp. 121-22.

2. Maj. William E. Merrill to Lt. Frederick A. Mahan, 7 Aug. 1880, Letters Sent by the Cincinnati and Pittsburgh District, 1873-1906, Entry 1281, Record Group 77, Federal Regional Records Center, Philadelphia, PA. Collection hereafter cited as Ltrs. Sent, 1873-1906, RG 77, FRRC. Mahan's reply has not been found, but the distance traveled by the *Thom* may have accounted for the differences in charges.

3. Maj. William E. Merrill to Commander George Dewey, 16 Oct. 1882, Ltrs. Sent, 1873-1906, RG 77, FRRC. Dewey's reply has not been found, but Merrill subsequently decided to increase the number of coils of chain around the drum and therefore lengthened the drum from 4′9 and ⅝″ to 5′4″.

4. James H. Harlow, "Description of a Derrick Used at Davis Island Dam," *Engineers' Society of Western Pennsylvania Proceedings* 1 (1881):25-28.

5. Ibid.

6. Lt. Frederick A. Mahan to Maj. William E. Merrill, 9 Sept. 1878, File 2173, Ltrs. Rec., 1871-1886, NARG 77; Maj. William E. Merrill to Lt. Frederick A. Mahan, 19 and 22 Oct. 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC. Merrill prescribed maximum lifting limits for the stiffleg derricks of 40 cubic feet or 3 tons.

7. *Pittsburgh Commercial Gazette,* 7 Oct. 1885. Revealing the public attitude toward safety at the time, the newspaper reported that no serious accidents had occurred at the project during construction; "only" three Irishmen were killed. When advising Mahan what to do about a man seriously injured on the job, Merrill wrote: "It is the rule in all large corporations to give the preference to men who have been injured in their service, and if you have any opening I wish you would give it to this man." See Maj. William E. Merrill to Lt. Frederick A. Mahan, 15 Dec. 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC.

8. Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 28 Nov. 1879, File 5121, Ltrs. Rec., 1871-1886, NARG 77; U.S. Army, Corps of Engineers, *Annual Report, 1880* (Washington, DC: Government Printing Office, 1881), pp. 1737-38, 1743.

9. Thomas P. Roberts, "Construction of Coffer-Dams," *Engineers' Society of Western Pennsylvania Proceedings* 21 (1905):307; Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 28 Nov. 1879, File 5121, Ltrs. Rec., 1871-1886, NARG 77.

10. Lt. Frederick A. Mahan to Maj. William E. Merrill, 28 July 1879, File 2105, Ltrs. Rec., 1871-1886, NARG 77; Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 20 Aug. 1879, File 2239, in ibid.; Lt. Frederick A. Mahan to Maj. William E. Merrill, 7 Aug. 1879, File 2382, in ibid.; Lt. Col. John G. Parke to Maj. William E. Merrill, 15 Sept. 1880, Ltrs. Sent, 1871-1886, NARG 77.

11. Carl B. Jansen, "Century of Progress Marks Many Improvements in Construction of Locks and Dams," *Civil Engineering* 18 (October 1948):628-33; *Pittsburgh Commercial Gazette,* 7 Oct. 1885.

12. Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 8 and 21 June 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC.

13. Maj. William E. Merrill to Lt. Frederick A. Mahan, 16 July 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC.

14. Maj. William E. Merrill to Lt. Frederick A. Mahan, 11 and 18 Sept. 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC; U.S. Army, Corps of Engineers, *Annual Report, 1895* (Washington, DC: Government Printing Office, 1896), p. 2361.

15. U.S. Army, Corps of Engineers, *Annual Report, 1879,* p. 1309; Maj. William E. Merrill to Lt. Frederick A. Mahan, 27 Sept. 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC.

16. Maj. William E. Merrill to Lt. Frederick A. Mahan, 9 Apr. 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC; Maj. William E. Merrill to Lt. Frederick A. Mahan, 3 May 1880, in ibid.

17. Maj. William E. Merrill to Lt. Frederick A. Mahan, 9 Apr. 1880, in ibid.; Merrill, "Historical Sketch of the Work of the United States in the Improvement of the Ohio River," p. 337; Maj. William E. Merrill to Lt. Frederick A. Mahan, 28 Dec. 1880, Ltrs. Sent, 1873-1906, RG 77, FRRC.

18. U.S. Army, Corps of Engineers, *Annual Report, 1880,* pp. 1753-56; Addison M. Scott, "General Notes on the Great Kanawha Improvement," *Transactions of the American Society of Civil Engineers* 31 (May 1894):546-47.

19. Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 12 Feb. 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC.

20. U.S. Army, Corps of Engineers, *Annual Report, 1880,* pp. 1753-56; Maj. William E. Merrill to Lt. Col. John G. Parke, 21 Sept. 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC.

21. Maj. William E. Merrill to Lt. Col. John G. Parke, 21 Sept. 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC; Maj. William E. Merrill to Lt. Frederick A. Mahan, 28 Dec. 1880, in ibid.; Maj. William E. Merrill to Alfred Pasqueau, 19 Jan. 1881, in ibid.; Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 19 Feb. 1881, in ibid. Merrill's correspondence with Pasqueau is printed in 26 *U.S. Court of Claims* 509, 8 June 1891.

22. 26 *U.S. Court of Claims* 509, 8 June 1891, p. 515.

23. Ibid., p. 514.

24. Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 22 Nov. 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC.

25. U.S. Army, Corps of Engineers, *Annual Report, 1881* (Washington, DC: Government Printing Office, 1882), p. 1912; Maj. William E. Merrill to H.A. Ramsay & Co., 19 May 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC; "Advertisement: Ohio River Improvement, Proposals for Iron Work at the Davis Island Dam," 5 Apr. 1881, in Addison M. Scott Papers, Marshall University Library, Huntington, WV. The Scott papers contain a large number of material advertisements, including specifications, for the Davis Island project and for other works on the Ohio and Kanawha rivers.

26. U.S. Army, Corps of Engineers, *Annual Report, 1881,* p. 1913; Johnson, *Men, Mountains and Rivers,* pp. 89-92, 178.

27. William Martin, "Description of Coffer Dam Used at Davis Island Dam," *Engineers' Society of Western Pennsylvania Proceedings* 1 (1882):275-79.

28. Ibid.; U.S. Army, Corps of Engineers, *Annual Report, 1882* (Washington, DC: Government Printing Office, 1883), pp. 1912-14.

29. Maj. William E. Merrill to Lt. William M. Black, 22 June 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC.

30. Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 22 June and 14 Sept. 1881, in ibid.; *Pittsburgh Commercial Gazette,* 7 Oct. 1885.

31. Lt. Col. John G. Parke to Maj. William E. Merrill, 25 March 1881, copy enclosed in File 750, General Correspondence, 1894-1923, NARG 77.

32. William Martin to Lt. Col. William E. Merrill, 21 Aug. 1891, Letters Received by the Cincinnati and Pittsburgh District, 1873-1906, Entry 1283, Record Group 77, Federal Regional Records Center, Philadelphia, PA (Collection hereafter cited as Ltrs. Rec., 1873-1906, RG 77, FRRC); *Pittsburgh Commercial Gazette,* 28 Sept. 1881.

VII: CONSTRUCTION COMPLETED

1. *Pittsburgh Gazette,* 6 Oct. 1884, prints the remarks heading the chapter; Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 22 Nov. 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC, reported a deficiency of funds had been incurred during the 1881 rush to finish the navigable pass. An editorial in *American Engineer* 3 (18 Feb. 1882):80, declared: "This work has been underway for several years, but Congress is not likely to do anything so wise as to provide for its completion for a couple of years yet, at much greater cost from flood damages." See also, *Pittsburgh Commercial Gazette,* 7 Oct. 1885.

2. U.S. Army, Corps of Engineers, *Annual Report, 1883* (Washington, DC: Government Printing Office, 1884), pp. 1511-18; William Martin, "Davis Island Dam, Ohio River," *Engineering News* 15 (15 May 1886):306-11.

3. U.S. Army, Corps of Engineers, *Annual Report, 1883,* pp. 1511-18.

4. Ibid.; "Advertisement: Ohio River Improvement, Proposal for Iron Work for the Davis Island Dam," 22 Mar. 1882, Addison M. Scott Papers, Marshall University Library, Huntington, WV; Maj. William E. Merrill to Maj. Gen. Horatio G. Wright, 2 May 1882, Ltrs. Sent, 1873-1906, RG 77, FRRC.

5. U.S. Army, Corps of Engineers, *Annual Report, 1889* (Washington, DC: Government Printing Office, 1890), pp. 1878-79; U.S. Army, Corps of Engineers, *Annual Report, 1898* (Washington, DC: Government Printing Office, 1898), pp. 2079-80; Maj. William E. Merrill to Capt. Frederick A. Mahan, 9 Feb. 1883, Ltrs. Sent, 1873-1906, RG 77, FRRC.

6. U.S. Army, Corps of Engineers, *Annual Report, 1884* (Washington, DC: Government Printing Office, 1885), pp. 1678-79; Maj. William E. Merrill to William Martin, 4 Jan. 1884, Ltrs. Sent, 1873-1906, RG 77, FRRC; Maj. William E. Merrill to George L. Douglas, 16 June 1884, in ibid.; Maj. William E. Merrill to Brig. Gen. John Newton, 26 May 1886, in ibid.; Maj. William E. Merrill to Pittsburgh Coal Exchange, 30 Jan. 1884, in ibid.; Maj. William E. Merrill to William Martin, 25 Apr. 1884, in ibid.

7. U.S. Army, Corps of Engineers, *Annual Report, 1884,* pp. 1784-85.

8. U.S. Army, Corps of Engineers, *Annual Report, 1885* (Washington, DC: Government Printing Office, 1886), p. 1775; U.S. Army, Corps of Engineers, *Annual Report, 1886* (Washington, DC: Government Printing Office, 1887), p. 1527; Joseph B. Bishop and Farnham Bishop, *Goethals, Genius of the Panama Canal: A Biography* (New York: Harper & Bros., 1930), pp. 58-61. Goethals' successor as deputy to Merrill was Lt. Lansing H. Beach, who served as Chief of Engineers from 1920-1924; Beach frequently visited Davis Island in connection with operational difficulties, but did not have a connection with project design or construction.

9. *Pittsburgh Commercial Gazette,* 26 Aug., 3 Sept., 8 Oct. 1884; Merrill, "Historical Sketch of the Work of the United States in the Improvement of the Ohio River," p. 337.

10. Maj. William E. Merrill to Lt. Col. William P. Craighill, 14 Oct. 1884, Ltrs. Sent, 1873-1906, RG 77, FRRC; Maj. William E. Merrill to William Martin, 13 Aug. 1884, in ibid. The diving equipment was purchased from A.J. Morse & Son of Boston.

11. *Pittsburgh Commercial Gazette,* 1 Sept. 1884; Henry S. Smith to Oliver Bros. & Phillips, 9 Oct. 1884, Ltrs. Sent, 1873-1906, RG 77, FRRC; "Advertisement: Ohio River Improvement, Lock Gate Timber for Davis Island Dam," 8 Feb. 1883, Addison M. Scott Papers, Marshall University Library, Huntington, WV; Maj. William E. Merrill to William Martin, 17 Feb. 1885, Ltrs. Sent, 1873-1906, RG 77, FRRC; "Circular: Ohio River Improvement, Maneuvering Boat for Davis Island Dam," 12 June 1885, Addison M. Scott Papers, Marshall University Library, Huntington, WV; U.S. Army, Corps of Engineers, *Annual Report, 1885,* pp. 1777-78.

12. Maj. William E. Merrill to Capt. Frederick A. Mahan, 31 Dec. 1881, Ltrs. Sent, 1873-1906, RG 77, FRRC; Maj. William E. Merrill to William Martin, 16 Mar. and 23 Nov. 1883, in ibid.; John W. Arras to Maj. Henry C. Newcomer, 4 Nov. 1909, Box 27, Pittsburgh District, Correspondence Relating to River Projects, 1906-1933, Entry 1289, RG 77, Federal Regional Records Center, Philadelphia, PA.

13. Maj. William E. Merrill to Morrison Foster, 17 Sept. 1885, Ltrs. Sent, 1873-1906, RG 77, FRRC; *Pittsburgh Post,* 8 Oct. 1885. None of the officers invited attended, at least in an official capacity; it would have required government travel orders at the expense of the taxpayers.

14. U.S. Army, Corps of Engineers, *Annual Report, 1886,* pp. 1528, 1540; *Pittsburgh Daily Post,* 6 Oct. 1885.

15. U.S. Army, Corps of Engineers, *Annual Report, 1886,* p. 1540; *Pittsburgh Daily Post,* 6 Oct. 1885.

16. Frederick Way, Jr., "Davis Island Dam Celebration," *S. & D. Reflector* 3 (June 1966):1-6.

17. Pittsburgh Chamber of Commerce, *Reports to the Chamber of Commerce upon the Opening of Davis Island Dam Together with Interesting Data* (Pittsburgh: Jos. Eichbaum & Co., 1886), p. 10; Way, "Davis Island Dam Celebration," pp. 1-6.

18. *Pittsburgh Commercial Gazette,* 7-8 Oct. 1885; *Pittsburgh Evening Penny Press,* 7 Oct. 1885.

19. *Pittsburgh Commercial Gazette,* 8 Oct. 1885.

20. Ibid.

21. Pittsburgh Chamber of Commerce, *Reports to the Chamber of Commerce upon the Opening of Davis Island Dam,* pp. 1-26; *Pittsburgh Commercial Gazette,* 8 Oct. 1885; J. Campbell Brandon, *History of the Bench and Bar of Butler County, Pennsylvania* (Butler, PA: Butler County Historical Society, 1968), pp. 207-09.

22. Pittsburgh Chamber of Commerce, *Reports to the Chamber of Commerce upon the Opening of Davis Island Dam,* pp. 28-31. Patrick Gragnon tried in 1976 to locate direct descendants of Col. Merrill without success. Merrill's grave is in St. Paul's Churchyard in Newport, Kentucky.

23. *Pittsburgh Commercial Gazette,* 8 Oct. 1885; *Pittsburgh Evening Penny Press,* 9 Oct. 1885. The name of the cabbage boat was not recorded. The first towboats through the lock were the *Monitor, William Wagoner,* and *Two Brothers;* see *Pittsburgh Commercial Gazette,* 10 Oct. 1885.

24. *Pittsburgh Commercial Gazette,* 7-8 Oct. 1885; Merrill, "Historical Sketch of the Work of the United States in the Improvement of the Ohio River," p. 338. Lt. Col. Henry C. Newcomer to Maj. Henry Jervey, 3 May 1911, Pittsburgh District, Correspondence Relating to River Projects, 1906-1933, Entry 1289, RG 77, Federal Regional Records Center, Philadelphia, PA, provided a final cost analysis. The total amount appropriated and received from other sources was $943,580.86, of which $940,832.31 was expended and the balance transferred to construction of the beartrap sluice in 1889. Comparison with Merrill's 1875 cost estimate of $505,488

indicates that a cost overrun of about 87 percent occurred; he never disguised the fact in his reports, however, that his estimates were based upon optimum construction conditions and also could be changed at any time because of the experimental character of the project. Because the figures do not allow for monetary inflation between 1875 and 1885, the final cost may be in fact closer to the original estimate than appears, and the cost does compare favorably with the costs of locks and dams subsequently constructed on the Ohio.

VIII: EXPERIMENTAL OPERATIONS

1. U.S. Army, Corps of Engineers, *Annual Report, 1885,* pp. 1799-1800, prints Merrill's remarks; John Arras, "The Ohio River," *Engineers' Society of Western Pennsylvania* 24 (June 1908):246-47.

2. Maj. William E. Merrill to Brig. Gen. John Newton, 26 Oct. 1885, Ltrs. Sent, 1873-1906, RG 77, FRRC; Maj. William E. Merrill to William Martin, 22 Jan. 1886, in ibid. Capt. L. Cramer of the *Barnard* later explained he could not control the tow and offered an apology which Merrill accepted, dropping legal action.

3. U.S. Army, Corps of Engineers, *Annual Report, 1886,* pp. 1540-42; Sibert, "The Improvement of the Ohio River," pp. 415-28; Arras, "The Ohio River," pp. 250-51; William Martin, "Report of Operations for October 1890," n.d., Ltrs. Rec., 1873-1906, RG 77, FRRC.

4. U.S. Army, Corps of Engineers, *Annual Report, 1886,* pp. 1540-42. Traffic through the lock was 19 passenger packets, 192 towboats, 3 model barges, 33 coalboats, 63 coal barges, 86 coalflats, and 8 small craft; traffic through the pass was 327 passenger packets, 13 freight steamers, 2,799 towboats, 180 model barges, 1,175 coalboats, 7,180 coal barges, 2,094 coalflats, 49 rafts, and 198 small craft, for the period from 7 Oct. 1885 through 30 June 1886. During the second year of operations, 1 July 1886 through 30 June 1887, 17,317 boats used the pass and 1,902 used the lock in 572 lockages (note the figures included the same boats passing up and down); see U.S. Army, Corps of Engineers, *Annual Report, 1887* (Washington, DC: Government Printing Office, 1888), p. 1799.

5. U.S. Army, Corps of Engineers, *Annual Report, 1885,* pp. 1802-03; U.S. Army, Corps of Engineers, *Annual Report, 1886,* pp. 1540-41; U.S. Army, Corps of Engineers, *Annual Report, 1889* (Washington, DC: Government Printing Office, 1890), pp. 1878-79; note in *S. & D. Reflector* 3 (September 1966):20.

6. U.S. Army, Corps of Engineers, *Annual Report, 1887,* pp. 1796-98.

7. Ibid.; U.S. Army, Corps of Engineers, *Annual Report, 1887,*

p. 1798; Riter and Conley Co. to Lt. Col. Amos Stickney, 22 Jan. 1895, Ltrs. Rec., 1873-1906, RG 77, FRRC; U.S. Army, Corps of Engineers, *Annual Report, 1895* (Washington, DC: Government Printing Office, 1896), p. 2361.

8. U.S. Army, Corps of Engineers, *Annual Report, 1887,* p. 1798; U.S. Army, Corps of Engineers, *Annual Report, 1890* (Washington, DC: Government Printing Office, 1891), pp. 2186-90; William Martin to Maj. William H. Heuer, 28 Apr. 1896, Ltrs. Rec., 1873-1906, RG 77, FRCC.

9. William Martin to Lt. Col. William E. Merrill, 14 Oct. 1890, Ltrs. Rec., 1873-1906, RG 77, FRRC; Maj. William H. Heuer to Brig. Gen. William P. Craighill, 6 May 1896, Ltrs. Sent, 1873-1906, RG 77, FRRC.

10. Maj. William E. Merrill to William Martin, 10 June 1887, Ltrs. Sent, 1873-1906, RG 77, FRRC; William Martin to Maj. William L. Sibert, 2 July 1904, Ltrs. Rec., 1873-1906, RG 77, FRRC.

11. U.S. Army, Corps of Engineers, *Annual Report, 1888* (Washington, DC: Government Printing Office, 1889), pp. 1670-72. On 3 Jan. 1888, during the ice, a coaltow crushed the maneuver boat, which was replaced with a 50 by 16 by 3-foot boat mounting a derrick on its bow.

12. U.S. Army, Corps of Engineers, *Annual Report, 1889,* pp. 1870-74, 1876-77, 1880. At times, as many as 2,500 loaded boats were afloat on the Davis Island pool during the 1890s, and at those times the Port of Pittsburgh had a greater vessel tonnage registered than any other port in the world.

13. U.S. Army, Corps of Engineers, *Annual Report, 1888,* p. 1666; Henderson, "Reminiscences of the River," pp. 236-37, provides an eyewitness account of the value of the project for navigation and for water supply.

14. William Martin, "Bear-Trap Gate in Davis Island Dam, Ohio River," *Journal of the Association of Engineering Societies* 16 (June 1896):208-10.

15. Ibid.; U.S. Army, Corps of Engineers, *Annual Report, 1885,* pp. 1859-66; Edward Wegmann, *The Design and Construction of Dams* (New York: John Wiley & Sons, 1922), p. 347; U.S. Army, Corps of Engineers, *Annual Report, 1889,* pp. 1878-79.

16. U.S. Army, Corps of Engineers, *Annual Report, 1891* (Washington, DC: Government Printing Office, 1892), pp. 2350-51.

17. U.S. Army, Corps of Engineers, *Annual Report, 1891,* p. 2340; U.S. Army, Corps of Engineers, *Annual Report, 1894* (Washington, DC: Government Printing Office, 1895), pp. 1867-70; note in *S. & D. Reflector* 3 (September 1966):20; Lt. Col. Amos Stickney to Chief of Engineers, 21 Mar. 1894, Ltrs. Sent, 1873-1906,

RG 77, FRRC; William Martin to Capt. William E. Craighill, 7 Dec. 1901, Ltrs. Rec., 1873-1906, RG 77, FRRC. Assistant Lockmasters in 1901 were David Faulk and Benjamin Wills; Assistant Dam Tenders were R.C. McCullough, George Nulton, and C.J. Cain.

18. Charles M. Wellons, "Operation of Ohio River Movable Dams," *National Waterways* 6 (July 1929):20-24, 64; John Arras, "Locks and Movable Dams of the Ohio River," *Professional Memoirs, Corps of Engineers* 3 (October 1911):535-51; U.S., Congress, House, *Report on Survey of Ohio River, Ohio and West Virginia, With a View to the Selection of Sites for Additional Locks and Dams,* H. Doc. 1159, 62d Cong., 2nd sess., 1912, p. 247.

19. U.S. Army, Corps of Engineers, *Annual Report, 1897* (Washington, DC: Government Printing Office, 1898), pp. 2356-57; John Arras, "Pittsburgh Waterway Improvement Problems," *National Waterways* 6 (October 1929):62.

20. U.S. Army, Corps of Engineers, *Annual Report, 1892* (Washington, DC: Government Printing Office, 1893), pp. 1981-83; William Martin to Lt. Col. William E. Merrill, 13 Sept. 1891, Ltrs. Rec., 1873-1906, RG 77, FRRC.

21. Lt. Col. William E. Merrill, 4th endorsement, 12 Aug. 1890, on H.O. Price to Sec. of Treasury William Windom, 21 July 1890, Ltrs. Rec., 1873-1906, RG 77, FRRC.

22. William Martin to Lt. William C. Langfitt, 10 Jan. 1895, in ibid.; William Martin to Maj. William Heuer, 25 May 1896, in ibid.

23. Sen. Boies Penrose to Sec. of War Elihu Root, 21 Jan. 1901, File 38042, General Correspondence, 1894-1923, NARG 77; William B. Rodgers to Maj. William H. Bixby, 21 Nov. 1900, Ltrs. Rec., 1873-1906, RG 77, FRRC; William Martin to Glen Bros., 21 Oct. 1904, Ltrs. Rec., 1873-1906, RG 77, FRRC. In 1897 a permit for drilling for oil and gas on Davis Island was denied; Maj. William H. Heuer to Chief of Engineers, 7 Aug. 1897, Ltrs. Rec., 1873-1906, RG 77, FRRC.

24. Maj. William E. Merrill to Brig. Gen. James C. Duane, 31 Jan. 1887, Ltrs. Sent, 1873-1906, RG 77, FRRC; Lt. Col. Henry C. Newcomer to Chief of Engineers, 24 Oct. 1911, General Correspondence, 1894-1923, NARG 77; U.S. Army, Corps of Engineers, *Annual Report, 1903* (Washington, DC: Government Printing Office, 1904), pp. 1671-72.

25. Maj. W.H. Bixby to Brig. Gen. John Wilson, 27 June 1899, General Correspondence, 1894-1923, NARG 77; Arras, "Locks and Movable Dams of the Ohio River," pp. 535-45.

IX: PROJECT EXTENSION

1. The lyrics at the chapter heading are from a song sung at the 1903 Ohio River Improvement Convention and written by J. Frank Tilley, leader of the Pittsburgh Coal Exchange, and printed in the *Pittsburgh Dispatch,* 15 Sept. 1903; U.S., Congress, House, *Ohio River between Wheeling and Pittsburgh,* H. Exec. Doc. 96, 50th Cong., 2nd sess., 1889, passim; U.S. Army, Corps of Engineers, *Annual Report, 1889,* pp. 1861-73.

2. U.S. Army, Corps of Engineers, *Annual Report, 1893* (Washington, DC: Government Printing Office, 1894), pp. 2456-64, 2533-35.

3. U.S., Congress, House, *Locks and Dams on the Ohio River in Pennsylvania,* H. Exec. Doc. 45, 52nd Cong., 2nd sess., 1892, pp. 1-4; U.S. Army, Corps of Engineers, *Annual Report, 1891,* pp. 2354-55; Johnson, *The Headwaters District,* p. 270.

4. William Martin to Lt. Col. William E. Merrill, 26 Sept. 1890, Ltrs. Rec. 1873-1906, RG 77, FRRC; U.S. Army, Corps of Engineers, *Annual Report, 1893,* p. 2485; *Louisville Courier-Journal,* 15 Dec. 1891.

5. Lewis M. Adams, "An A-Frame Movable Top to Provide Increased Depths above Fixed Dams," *Professional Memoirs, Corps of Engineers* 3 (April 1911):315-35; note in *Engineering News* 52 (17 November 1904):443; Leland R. Johnson, *Engineers on the Twin Rivers: A History of the U.S. Army Engineers, Nashville District, 1769-1978* (Nashville: U.S. Army Engineer District, 1978), pp. 194-95.

6. Frederick Way, Jr., "*Virginia*'s First Season," *S. & D. Reflector* 2 (June 1965):1-6.

7. U.S. Army, Corps of Engineers, *Annual Report, 1896* (Washington, DC: Government Printing Office 1897), pp. 2120-22; "Advertisement: Locks for Movable Dams Nos. 2, 3, 4 and 5, Ohio River," 23 Sept. 1897, Addison M. Scott Papers, Marshall University Library, Huntington, WV; note in *Engineering News* 37 (25 February 1897):113; Sibert, "The Improvement of the Ohio River," p. 400.

8. John L. Vance, "Sketch of Ohio River Improvements," *Ohio Archaeological and Historical Publications* 18 (1909):418; Maj. William H. Bixby to Brig. Gen. John Wilson, 30 Jan. 1900, File 33792, General Correspondence, 1894-1923, NARG 77; Johnson, *The Headwaters District,* pp. 158-59.

9. Col. William H. Bixby to Brig. Gen. John Wilson, 31 Oct. 1900, File 37227, General Correspondence, 1894-1923, NARG 77.

10. Capt. William E. Craighill to William Martin, 9 Dec. 1901, Ltrs. Rec., 1873-1906, RG 77, FRRC; Capt. William E. Craighill to Brig. Gen. G.L. Gillespie, 15 Oct. 1902, in ibid.

11. Senator Matthew S. Quay to Brig. Gen. G.L. Gillespie, 17 Jan. 1902, File 41804, General Correspondence, 1894-1923, NARG 77.

12. Sec. of War Elihu Root to Chief of Engineers, 25 Feb. 1903, and related correspondence in File 37227, General Correspondence, 1894-1923, NARG 77.

13. Col. G.J. Lydecker to Brig. Gen. G.L. Gillespie, 21 Aug. 1902, Ltrs. Rec., 1873-1906, RG 77, FRRC; Maj. William L. Sibert to Col. G.J. Lydecker, 21 Jan. 1902, File 6938, General Correspondence, 1894-1923, NARG 77; Maj. William L. Sibert to Brig. Gen. A. Mackenzie, 1 May 1905, File 55189, General Correspondence, 1894-1923, NARG 77.

14. U.S. Army, Corps of Engineers, *Annual Report, 1900* (Washington, DC: Government Printing Office, 1901), pp. 3140-45; *Pittsburgh Post,* 21 Aug. 1902; *Pittsburgh Chronicle-Telegraph,* 21 Aug. 1902; William Martin to Maj. William L. Sibert, 22 Jan. 1902, Ltrs. Rec., 1873-1906, RG 77, FRRC; U.S. Army, Corps of Engineers, *Annual Report, 1906* (Washington, DC: Government Printing Office, 1907), pp. 1588-90; U.S. Army, Corps of Engineers, *Annual Report, 1907* (Washington, DC: Government Printing Office, 1908), pp. 1727-28.

15. Maj. William L. Sibert to Brig. Gen. G.L. Gillespie, 31 Aug. 1903, Ltrs. Sent, 1873-1906, RG 77, FRRC; William L. Sibert, "Artificial Waterways in the United States," *Transactions of the American Society of Civil Engineers* 54 (1905):270-82.

16. Sibert, "Artificial Waterways in the United States," p. 282; Henry C. Newcomer, "Movable Tops for Fixed Dams," *Professional Memoirs, Corps of Engineers* 2 (April 1910):202-12.

17. U.S. Army, Corps of Engineers, *Annual Report, 1905* (Washington, DC: Government Printing Office, 1906), pp. 1842-43; John Arras to District Engineer, 18 June 1914, "Dam No. 1, Ohio River," Box 16, Pittsburgh District, Correspondence Relating to River Projects, 1906-1933, Entry 1289, RG 77, Federal Regional Records Center, Philadelphia, PA.

18. Malcolm Elliott, "Vertically Framed Mitering Lock Gates," *Military Engineer* 7 (July 1915):414; U.S. Army, Corps of Engineers, *Annual Report, 1912* (Washington, DC: Government Printing Office, 1913), pp. 2332-33. The switch from the Merrill rolling gates to mitering gates in 1914 resulted from continuing maintenance problems with the rolling gates and the great difficulties experienced when the gate recesses filled with sand during high water, a not infrequent event.

19. John Arras to District Engineer, 18 June 1914, "Dam No. 1, Ohio River," Box 16, Pittsburgh District, Correspondence Relating to River Projects, 1906-1933, Entry 1289, RG 77, Federal Regional Records Center, Philadelphia, PA.

20. Ibid.

21. Johnson, *The Headwaters District,* pp. 165-67, 212-13; "Fixed Dams to Replace Movable Dams on the Upper Ohio," *Engineering News* 77 (22 March 1917):486-87; J. Franklin Bell, "The Emsworth and Davis Island Dams," *Military Engineer* 15 (September 1923):405-08; *Pittsburgh Gazette Times,* 17 Jan. 1915; U.S., Congress, House, *Ohio River,* H. Doc. 1695, 64th Cong., 2nd sess., 1916, passim.

22. Bell, "The Emsworth and Davis Island Dams," pp. 405-08; U.S. Army, Corps of Engineers, *Annual Report, 1922* (Washington, DC: Government Printing Office, 1923), p. 1353.

23. Maj. J. Franklin Bell to T.W. Guthrie, 16 Nov. 1922, Pittsburgh District, Correspondence Relating to River Projects, 1906-1933, Entry 1289, RG 77, Federal Regional Records Center, Philadelphia, PA; U.S. Army, Corps of Engineers, *Annual Report, 1923* (Washington, DC: Government Printing Office, 1924), p. 1228; U.S. Army, Corps of Engineers, *Annual Report, 1924* (Washington, DC: Government Printing Office, 1925), p. 1217. Emsworth Locks opened to navigation on 1 Sept. 1921, Davis Island ceased operation on 3 Aug. 1922, and Lock 2 ceased operation on 23 Aug. 1922. The site of Davis Island Lock was sold at public auction on 12 June 1923 to the Pittsburgh, Fort Wayne and Chicago Railway. The Pittsburgh District in 1984 removed part of the Davis Island Lock land wall and machinery as a hazard to navigation.

24. Johnson, *The Headwaters District,* pp. 158-59; U.S., Congress, House, *Ohio River,* H. Doc. 492, 60th Cong., 1st sess., 1908, is the Lockwood Board report.

25. U.S., Congress, House, *Ohio River,* H. Doc. 492, 60th Cong., 1st sess., 1908, pp. 1-21.

26. Johnson, *Men, Mountains and Rivers,* p. 127-33; Johnson, *The Falls City Engineers,* pp. 174-80; Johnson, *The Headwaters District,* p. 160.

27. Johnson, *The Headwaters District,* pp. 160-62.

28. Johnson, *The Falls City Engineers,* pp. 188-89, 227-51.

29. Ibid., pp. 246-51; C.L. Hall, "Economics of the Ohio River Improvement," *Transactions of the American Society of Civil Engineers* 103 (1938):1527-78; Minard I. Foster, "Broad Scope of Navigation's Economic Impact," *Journal of Waterways and Harbors Division, American Society of Civil Engineers* 95 (February 1969):23-34; Braxton B. Carr, "Barge Transportation — Energizer of Production and Marketing," *Journal of Waterways and Harbors Division, American Society of Civil Engineers* 95 (May 1969):163-73.

X: PROJECT INFLUENCES

1. Transcript of Haupt testimony, 20 Apr. 1886, in Addison M. Scott Papers, Marshall University Library, Huntington, WV. Haupt,

a distinguished civil engineer and son of Herman Haupt, served as an expert witness for the plaintiff.

2. William Martin to Maj. Amos Stickney, 6 Sept. 1892, Ltrs. Rec., 1873-1906, RG 77, FRRC; Johnson, *The Headwaters District,* p. 212.

3. Henry Smith to William Martin, 12 Oct. 1883, Ltrs. Sent, 1873-1906, RG 77, FRRC; George H. Anderson to Brig. Gen. G.L. Gillespie, 16 Jan. 1904, File 49824, General Correspondence, 1894-1923, NARG 77; Charles H. West to Col. C.R. Edwards, 15 June 1904, File 51649, General Correspondence, 1894-1923, NARG 77.

4. Brig. Gen. G.L. Gillespie to George H. Anderson, 20 Jan. 1904, File 49824, General Correspondence, 1894-1923, NARG 77; Maj. W.M. Adams to Lt. Col. William E. Merrill, 26 Dec. 1891, Ltrs. Rec., 1873-1906, RG 77, FRRC.

5. *Pittsburgh Post,* 8 Oct. 1885; Maj. William E. Merrill to William Martin, 6 Dec. 1888, Ltrs. Sent, 1873-1906, RG 77, FRRC.

6. 26 *U.S. Court of Claims* 509; Maj. William E. Merrill to Brig. Gen. John Newton, 8 Mar. 1886, Ltrs. Sent, 1873-1906, RG 77, FRRC.

7. 26 *U.S. Court of Claims* 509; U.S. Army, Corps of Engineers, *Annual Report, 1900,* p. 3323; Lewis M. Haupt to editor, 1 Aug. 1894, in *Engineering News* 32 (9 August 1894):113. A collection of papers relating to the Pasqueau case are in Addison M. Scott Papers, Marshall University Library, Huntington, WV.

8. Theodore E. Burton to Maj. Gen. William H. Bixby, 23 Aug. 1911, File 72788, General Correspondence, 1894-1923, NARG 77; Dennis H. Mahan and Frederick A. Mahan, *A Treatise on Civil Engineering* (New York: John Wiley & Sons, 1902), pp. 494-533; Frederick A. Mahan, "Inland Transportation," *Transactions of the American Society of Civil Engineers* 29 (1893):97-127; Frederick A. Mahan, "Organization of the Services of Public Works in France," *Professional Memoirs, Corps of Engineers* 5 (January 1913):99-121.

9. Johnson, *The Headwaters District,* pp. 160-70, 246-53.

10. Roald Tweet, *A History of the Rock Island District, Corps of Engineers* (Rock Island: U.S. Army Engineer District, 1975), pp. 102-05.

11. Merrill, "Historical Sketch of the Work of the United States in the Improvement of the Ohio River," p. 338; Johnson, *The Falls City Engineers,* pp. 228-29.

12. William M. Hall, "Some Notes on the Location and Construction of Locks and Movable Dams on the Ohio River," *Transactions of the American Society of Civil Engineers* 86 (1923):107-08, 162-64.

13. Johnson, *The Headwaters District,* p. 153; Newcomer, "Movable Tops for Fixed Dams," pp. 202-12.

14. "Movable Dams on the New York State Barge Canal," *Engineering News* 64 (8 December 1910):611-15; Henry Van Alstyne, "Work on the 1,000-ton Barge Canal and on Improved Highways in New York," *Engineering News* 57 (3 January 1907):5.

15. "American Hydraulic Gates," *Journal of the Association of Engineering Societies* 16 (June 1896):177-207.

16. Ibid., pp. 178-79; note in *Engineering News-Record* 89 (10 August 1922):247; U.S. Army, Corps of Engineers, *Annual Report, 1890,* p. 2367. But note that Poirée in 1853 used a segmental arc gate at La Monnaie Dam on the Seine River; see Francis Vernon-Harcourt, *A Treatise on Rivers and Canals,* pp. 134-35.

17. Johnson, *Men, Mountains and Rivers,* pp. 137-38 (The first Krupp roller dam was built in 1902 on a tributary of the Main River near Schweinfurt; Marmet Dam on the Kanawha River was the first roller dam built in the United States.); Johnson, *The Headwaters District,* pp. 248-52; "New Crest Gate," *Engineering News-Record* 118 (6 May 1937):678; A. Streiff, "A New Type of Crest Gate," *Engineering News-Record* 118 (17 June 1937):897; Wilfred Bauknight, "New Crest Gate for Dams," *Engineering News-Record* 118 (6 May 1937):665-66.

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